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INSIDE

NATURE'S SATNAVS
MEET THE ANIMALS BORN WITH A BUILT-IN GPS

# 3D PRINTING

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Inside the machines perfectly adapted for frozen terrain

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# WELCOME

## The magazine that feeds minds!


**Page 38**
How are vehicles engineered to tame even the deepest snow and most slippery ice?

Few technologies can lay claim to sparking a 21st-century industrial revolution, but right now 3D printing surely has to be at the top of the list.

Its potential is unrivalled. Whether it's food, clothes, vehicle parts or even replacement organs, it's making its presence felt. Even more groundbreaking possibilities are on the horizon, including emergency shelters after natural disasters, bespoke medication and even space colonies. We focus on the machines powering this manufacturing renaissance and talk to an expert about what the future holds for 3D printing.

But it's not all about the future – we can learn a lot from the past too. In History, we explain how Buckingham Palace emerged out of a marsh, the forgotten art of candlemaking, plus the origins of Japan's *biggest* sport – in more ways than one: sumo wrestling. Enjoy the issue.

Adam

**Adam Millward**
Deputy Editor

## Meet the team…

**Marcus**
**Senior Designer**
Flooding seems to be on everyone's lips at the moment so what better time to cover them? Turn to page 26 to see how they change our world.

**Jackie**
**Research Editor**
3D printing gives us the chance to create pretty much anything. Printed rocket parts and prosthetics are just the tip of the iceberg!

**Erlingur**
**Sub Editor**
I've always been curious about the Milky Way galaxy, our immediate neighbourhood yet mind-numbingly big. Hitch a ride to it on page 48.

**Helen**
**Senior Art Editor**
If I had a superpower, I'd choose to be invisible for a day. Thanks to the latest scientific advancements, it could soon be a reality.

## What's in store…

**The huge amount of information in each issue of How It Works is organised into these key sections:**


**Science**
Uncover the world's most amazing physics, chemistry and biology

**Technology**
Discover the inner workings of cool gadgets and engineering marvels

**Transport**
Everything from the fastest cars to the most advanced aircraft

**Space**
Learn about all things cosmic in the section that's truly out of this world

**Environment**
Explore the amazing natural wonders to be found on planet Earth

**History**
Step back in time and find out how things used to work in the past

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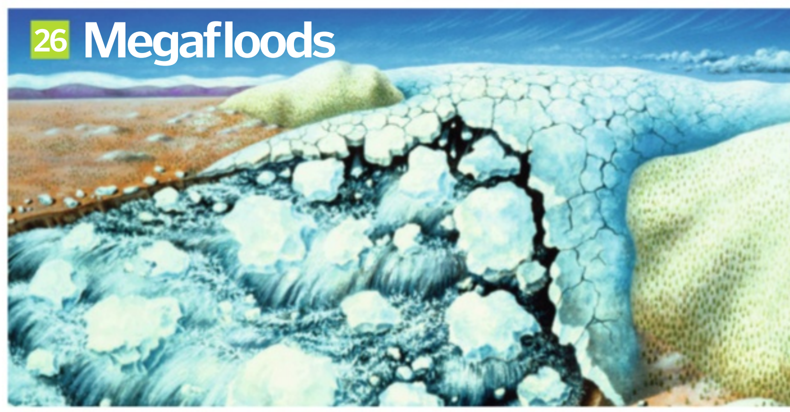
Discover the innovative technology powering 3D printers and why additive manufacturing is set to be a 21st-century industrial revolution





## Meet the experts…

**Vivienne Raper**
**Megafloods**
With all the disruption caused by rain and subsequent floods in Britain recently, Vivienne is here to explain how floods – especially those of the mega variety – have played a major role in shaping our world.

**Luis Villazon**
**3D printing**
Luis introduces us to one of the greatest technological breakthroughs of the modern era, looking at how 3D printing works and whether there are any limits to its seemingly endless potential.

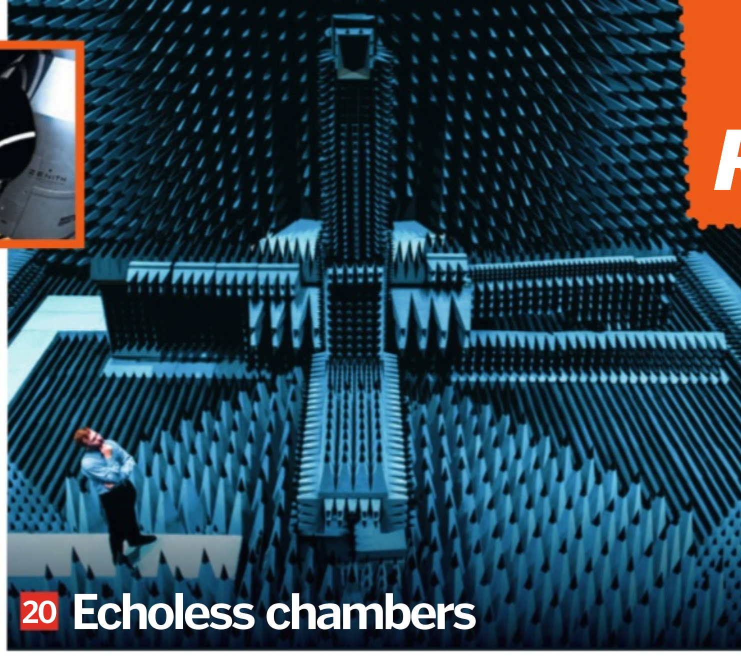
**Giles Sparrow**
**Guide to the galaxy**
Space expert Giles is back to reveal the origins of the Milky Way, where we fit in and how it stacks up to other galaxies throughout the cosmos.

**Tim Hopkinson-Ball**
**Buckingham Palace**
Ever wondered what goes on behind closed doors at Buckingham Palace? Tim takes us on a private tour around the Queen's London pad.

**Laura Mears**
**The science of invisibility**
Laura had to look pretty hard to seek out the science and technology with the power to make things both big and small disappear – in the main Science feature she reveals all…

How can anyone survive freefall from 39km above the Earth? Find out on pg 58















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# GLOBAL EYE

Showcasing the incredible world we live in


# Opportunity's ten years on Mars

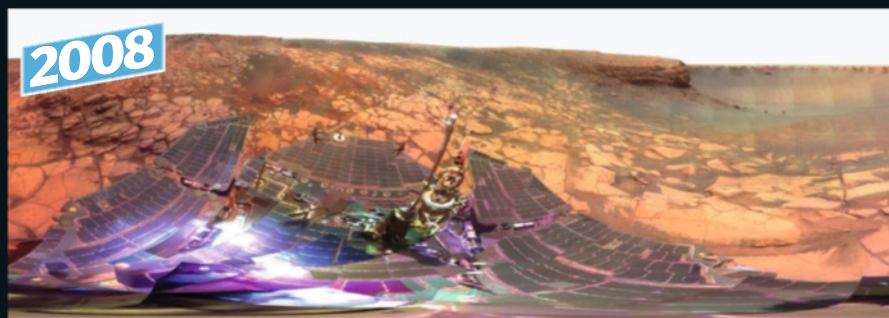
## NASA's longest-operating rover is still blazing trails on the Red Planet

The Curiosity rover may have grabbed a lot of the limelight since 2012, but Opportunity is truly the veteran of Martian exploration, having been active since 2004. Over the last decade Opportunity and its fellow Mars Exploration Rover, Spirit, have made some groundbreaking discoveries, including meteorites from other worlds and ever-growing evidence that the Red Planet's environment was previously much warmer and wetter. While its companion, Spirit, stopped moving in 2009 and has been incommunicado since 2010, Opportunity is still going strong. Major technology on board includes its panoramic camera (Pancam) to scope out surrounding terrain, tools for breaking up rock and brushing away dust, plus spectrometers for analysing the physical and chemical properties of Mars's soil. Since it landed, Opportunity has travelled some 39 kilometres (24 miles) and is currently investigating an unusual surface rock at the edge of the Endeavour Crater. While it has already achieved so much, Opportunity is far from retirement. "We're looking at the legacy of Opportunity's first decade… but there's more good stuff ahead," said the mission's principal investigator, Steve Squyres. "We are examining a rock right in front of the rover that is unlike anything we've seen before. Mars keeps surprising us, just like in the very first week of the mission."

**2004:** The first panoramic look at Meridani Planum plain where Opportunity landed a decade ago
**2005:** A shot looking back at its own tracks on the dusty surface of Mars
**2006:** Panoramic shot from the edge of Erebus Crater
**2007:** A satellite shot showing Opportunity's route around the edge of Victoria Crater
**2008:** Studying the multicoloured bands of rock at the rim of Victoria Crater
**2009:** The Block Island meteorite is one of the largest ever found on the Red Planet
**2010:** A mosaic shot that reveals what the Martian dunes would look like to our eyes
**2011:** Approaching the Endeavour Crater where the rover is still exploring today
**2012:** Martian spherules, or 'blueberries', may be the result of water erosion or volcanic activity, according to recent speculation by astronomers
**2013:** Opportunity captures a dust storm in this before-and-after shot of the sky
**2014:** The rover takes a self-portrait with its Pancam to celebrate its tenth year on Mars

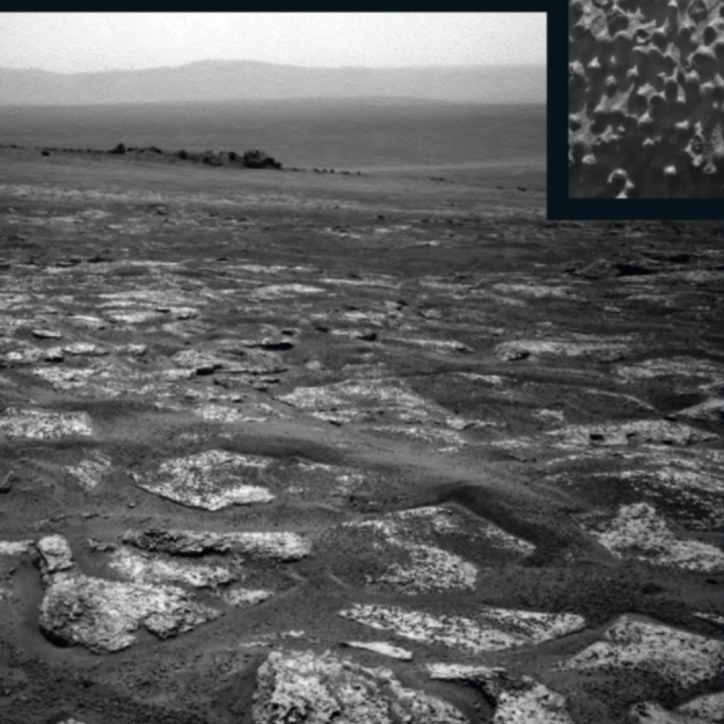

2005


2007
Meters
150
300

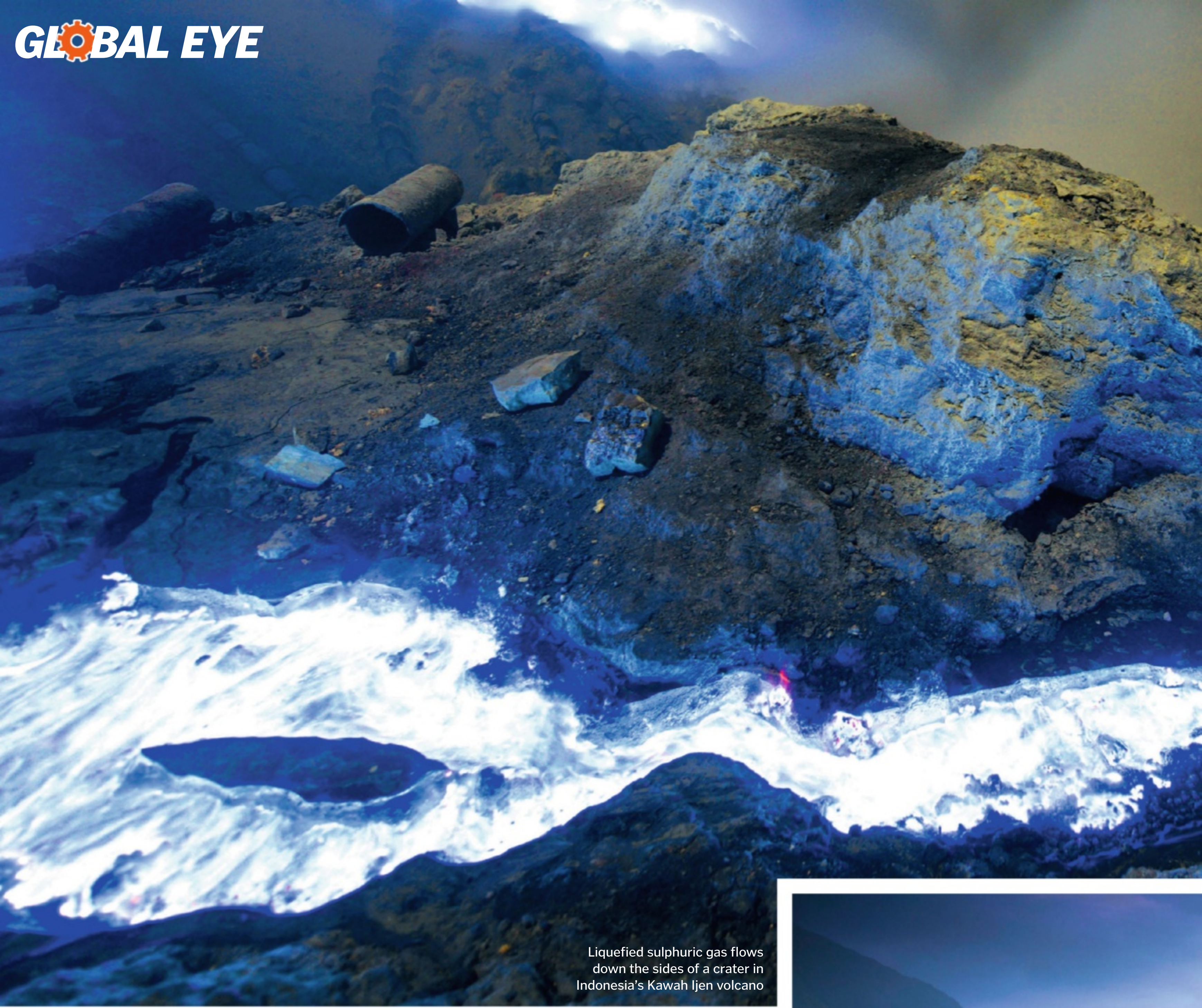

2008


2013


2012




2014



Liquefied sulphuric gas flows down the sides of a crater in Indonesia's Kawah Ijen volcano

# Volcano reveals its true colours

## Amazing shots inside Indonesian crater show that volcanoes get the blues too

Despite looking like an extra-terrestrial phenomenon, this neon-blue liquid tearing down a mountainside is very much of this world. But even though it's seeping from the Kawah Ijen volcano on Java in Indonesia, it isn't blue lava, as you might expect. In fact, it's sulphuric gas being forced through cracks in the ground as it comes into contact with air. Emerging at around 600 degrees Celsius (1,112 degrees Fahrenheit), some of the gas liquefies and flows down the walls of the crater toward a jewel-green lake brimming with hydrochloric acid. Pipes have been fitted to many of these vents in order to collect the molten sulphur in mats where it cools into its yellow solid form and is harvested. Sulphur is a component in many products, including fertilisers, and a vital part in the manufacture of others, like rubber, paint and textiles.

The future path of weaponry might be lit by lasers

# Mega-laser points to future of war

A 30KW laser – the most powerful to date – has been successfully fired. Lockheed Martin has combined several fibre lasers in a process known as spectral beam combining (SBC). According to John Wojnar of Lockheed's laser systems division: "Lasers with slightly different wavelengths go into a combiner and come out as a single beam." Up until now lasers' potential has been limited by both the power and quality of the beam. This prototype brings the military closer to 'speed of light' armaments, which are far more accurate and cost-effective than traditional missiles.

# GM tomatoes to help save lives

The juice from genetically modified tomatoes, shown to have health benefits for those suffering with cardiovascular disease and cancer, is to go on sale in the UK in the coming months. The purple fruit gets its unusual colouring from the pigment anthocyanin, naturally found in blueberries and plums. This antioxidant limits the damage caused by unstable molecules in the body known as free radicals, which can destroy cells by interfering with their subatomic structure. Developed at the John Innes Centre in Norwich, UK, the purple tomatoes have been grown in Canada due to more relaxed laws around GM crops than Europe. According to Professor Cathie Martin, "When mice [with cancer] were fed a diet supplemented with purple tomatoes, they lived 30 per cent longer than those with a diet supplemented with red tomatoes." But she cautions that while it offers "complementary health advantages… [it] is not a standalone therapy."

# British Science Festival returns to Birmingham

In September 2014, the British Science Festival is taking over the streets of Birmingham, UK. The city is currently leading the field in many of the emerging disciplines of the 21st century. Its major research themes include sustainable environment, energy and resources, transport technology, genetics, cancer treatment and particle physics, to name just a few.

It won't be the first time the festival has visited the city. The British Science Festival first came to Birmingham back in 1938 and more recently in 2010. Four years ago, more than 55,000 people attended the busy six-day programme.

The University of Birmingham can boast six Nobel prize winners among its prestigious science alumni and staff, including biochemist Sir Paul Nurse – president of the British Science Association in 2014 – and physicist Francis Aston. For updates on the festival, you can visit **www.britishsciencefestival.org**.

© Alamy; Corbis; NASA

GLOBAL EYE

# 10 COOL THINGS WE LEARNED THIS MONTH

## Holodecks help ready soldiers for war

Long gone are the days of training videos. Today's technology is allowing for a much more hands-on experience. While simulators have been improving for years, none has come as close to offering such a realistic experience as the Virtual Immersive Portable Environment (VIPE). Developed by Northrop Grumman, VIPE combines a 360-degree screen, projectors and Microsoft's Kinect tracking system to create a lifelike environment that reacts to the user's movements instantly – a bit like the famous holodecks in *Star Trek*. Because VIPE is wired up to the internet, multiple soldiers can participate in a single training exercise, no matter where they are in the world.

## Zinc is a common cold's nemesis

One of the most widely used metals can help fight the rhinovirus – the major cause of common colds. Zinc can shorten the length of a cold by up to two days. Lab studies revealed that the secret lies, oddly, in the metal's ability to *suppress* our immune system. By latching on to a certain protein, inflammation was significantly reduced, speeding up recovery. It's not all good news, though, as some participants reported a metallic taste and nausea.

## Solar System was once a cosmic snow globe

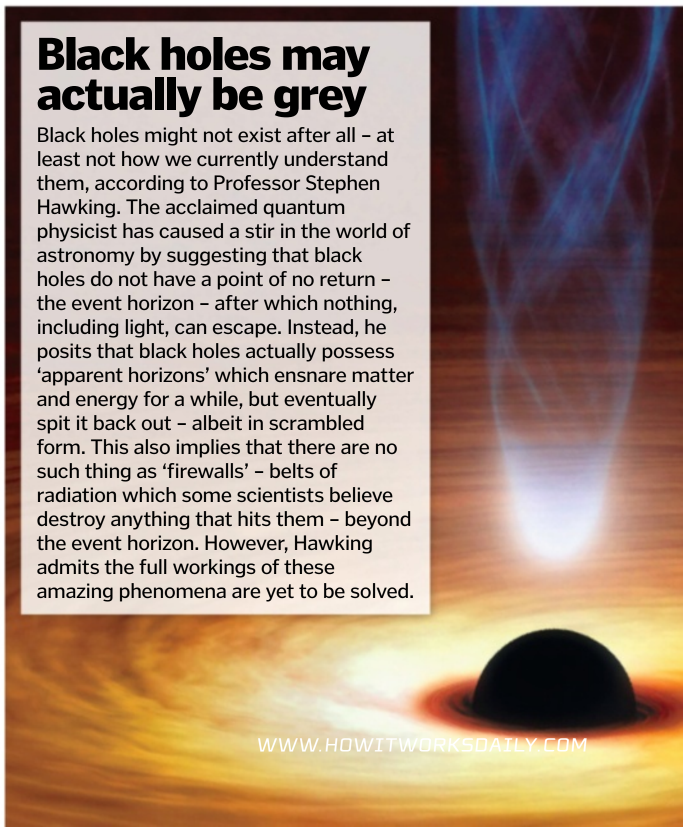
With each of the eight planets on its own predictable path around the Sun, our Solar System seems like an orderly place, but this wasn't always the case. In fact, according to the Harvard-Smithsonian Center for Astrophysics, the early Solar System was in total disarray – with celestial bodies flying all over, a bit like the flakes in a shaken-up snow globe. The evidence lies in the Asteroid Belt. What's always perplexed astronomers the rocks' diversity; how did asteroids from vastly different regions of space end up here? The answer seems to be restless planets migrating back and forth, with the smaller asteroids pushed around at their mercy. Some think Jupiter may once have been as close to the Sun as Mars is today.

## A single bedbug can start a colony

It's always been something of a mystery why bedbugs are so difficult to get rid of, but new research by the University of Sheffield has shed some light on their resilience. The new genetic analysis has revealed an entire infestation can stem from a single pregnant bedbug that evades detection. Numbers of these insects in British cities have been on the rise since the Eighties, attributed to increased international travel and a growing resistance to the chemicals used to exterminate them.

## Beads clean clothes better than water

A new take on the washing machine does away with almost all the water guzzled by a standard washer and replaces it with tiny beads. Developed at Leeds University School of Textiles, the nylon-based beads are much more efficient at removing stains than water. During a cycle a small amount of water (a tenth of that used normally) mixed with detergent is added to the drum, along with over a million beads. The humid conditions cause the nylon polymers to expand, leaving gaps, making the beads super-absorbent; this means any dirt on the clothes is sucked up. As well as saving dramatically on water, the manufacturer says that beads can be reused for up to 500 washes and they can also be recycled.



## Black holes may actually be grey

Black holes might not exist after all – at least not how we currently understand them, according to Professor Stephen Hawking. The acclaimed quantum physicist has caused a stir in the world of astronomy by suggesting that black holes do not have a point of no return – the event horizon – after which nothing, including light, can escape. Instead, he posits that black holes actually possess 'apparent horizons' which ensnare matter and energy for a while, but eventually spit it back out – albeit in scrambled form. This also implies that there are no such thing as 'firewalls' – belts of radiation which some scientists believe destroy anything that hits them – beyond the event horizon. However, Hawking admits the full workings of these amazing phenomena are yet to be solved.

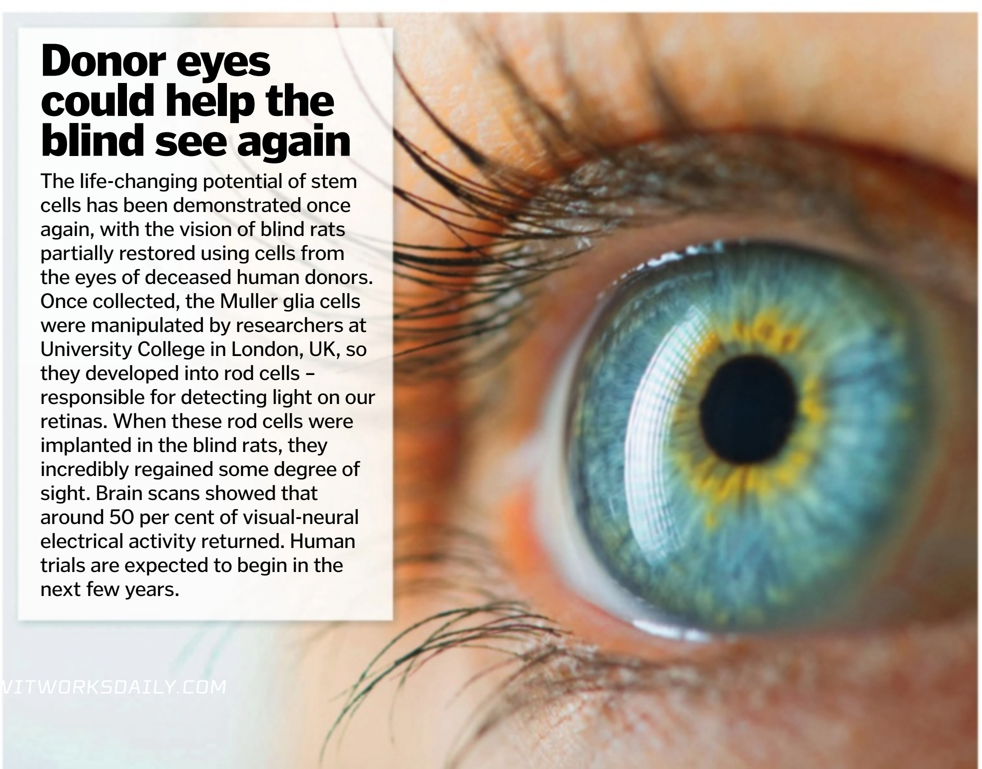
© Alamy; Corbis; Incheon Robot Land; NASA; Northrop Grumman; Xeros

## Robot theme park is on the way

A new kind of theme park dedicated to all things robotic is currently being built in South Korea. While attractions will include droid-based rides, shops, an aquarium with mechanical fish and the opportunity to build your own bot, Robot Land will be just as much about education and research as it is fun. Training facilities and an R&D department on the site will focus on developing the robots of the future. The park is currently slated to open in 2016.

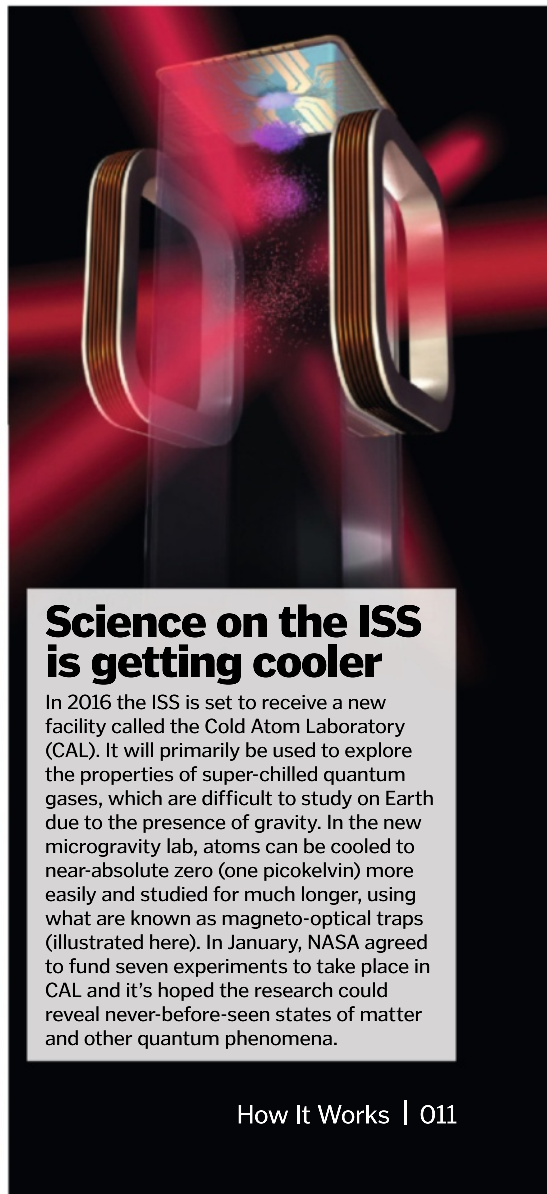
## Cuttlefish are inspiring future camouflage

By examining the microanatomy of the cuttlefish – namely the features enabling it to change its skin colour and pattern – marine biologists think it could serve as a blueprint to make smart clothing that can blend in with its environment. The creature uses multilayered organs called chromatophores containing luminescent protein to adapt to its surroundings in seconds. Beyond stealth applications, it's thought this natural mechanism could be emulated in new forms of paint and cosmetics too.



## Donor eyes could help the blind see again

The life-changing potential of stem cells has been demonstrated once again, with the vision of blind rats partially restored using cells from the eyes of deceased human donors. Once collected, the Muller glia cells were manipulated by researchers at University College in London, UK, so they developed into rod cells – responsible for detecting light on our retinas. When these rod cells were implanted in the blind rats, they incredibly regained some degree of sight. Brain scans showed that around 50 per cent of visual-neural electrical activity returned. Human trials are expected to begin in the next few years.



## Science on the ISS is getting cooler

In 2016 the ISS is set to receive a new facility called the Cold Atom Laboratory (CAL). It will primarily be used to explore the properties of super-chilled quantum gases, which are difficult to study on Earth due to the presence of gravity. In the new microgravity lab, atoms can be cooled to near-absolute zero (one picokelvin) more easily and studied for much longer, using what are known as magneto-optical traps (illustrated here). In January, NASA agreed to fund seven experiments to take place in CAL and it's hoped the research could reveal never-before-seen states of matter and other quantum phenomena.

# 3D PRINTING

Discover the technology behind the 21st-century industrial revolution being printed layer by layer…

# 5 TOP FACTS
## 3D PRINTING TECHNIQUES

**Stereolithography**
1 A liquid plastic called a photopolymer is 'cooked' with a focused beam of ultraviolet light. The model is lowered deeper into the photopolymer bath as each layer sets.

**Fused deposition modelling**
2 A spool of plastic filament is fed through a heating element to melt it. A platform is moved beneath the element to paint the liquid plastic on.

**Selective laser sintering**
3 A laser heats a thin layer of fine metal or plastic powder to fuse it solid. New layers of powder are added on top of each other to build up the finished model.

**Binder jetting**
4 This is like selective laser sintering, except that the powder is plaster-of-Paris and an inkjet head delivers a liquid binder to glue the plaster instead of melting it.

**Laminated object manufacturing**
5 A sheet of paper is cut using a laser or tungsten knife. The excess is pulled away before another sheet is glued on top and the process repeats.

**DID YOU KNOW?** An F-18 fighter jet contains about 90 3D-printed parts – it's cheaper to create maintenance spares this way

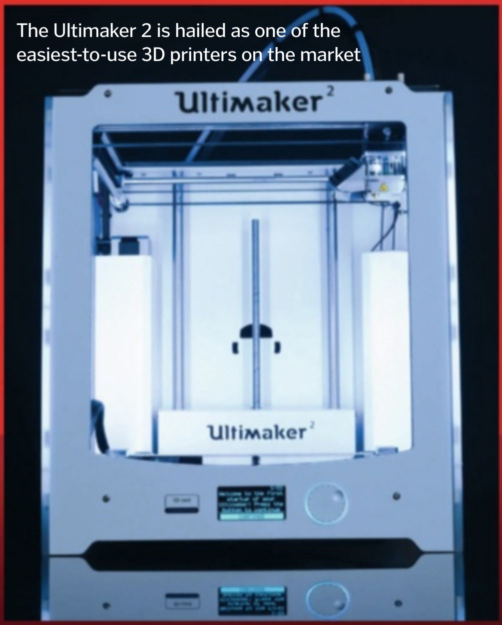
Over the 18th and 19th centuries the Industrial Revolution took manufacturing out of the hands of the common man and into the factories. The 3D printer has the potential to reverse this.

The automated production of intricately shaped objects from a 3D computer design isn't new. Computerised numerical control (CNC) milling machines have been around since the Fifties. But CNC works by cutting material away from a solid block and there are lots of shapes that are physically impossible to make in this way. Imagine trying to make a hollow sphere, for example; unless the cutting tool can reach the inside, there's no way to do it. 3D printing works in reverse: you start with nothing and progressively add material in layers to build up the shape you want. This places far fewer restrictions on the design. Depending on the 3D-printing technique, it is possible to build intricate honeycomb structures that save weight without sacrificing strength and even objects that have moving parts – such as a working gear train – all printed in a single pass, with no need for assembly afterward. The 3D printer has been compared to the printing press, but, in fact, it's a good deal more revolutionary than that. The printing press brought reading to the masses but it wasn't until the word processor and the dot-matrix printer that ordinary people could actually write words of their own in any quantity. Now 3D printers are poised to democratise manufacturing. This isn't just about copying existing factory-produced objects. For the first time in history, we all have the power to physically create and manufacture just about anything we can imagine ourselves.

3D printing is also called additive manufacturing because it works by adding new material in layers. There are several different techniques, depending on the material you want to build from. The earliest system, called stereolithography, was invented in 1986 by Charles Hull. He used a special resin that hardens on exposure to ultraviolet light.

By scanning a beam of UV light over the surface of a bath of the resin, he could create a thin layer of plastic. The floor of the bath was then lowered slightly to sink the completed layer below the surface of the liquid resin and the light beam made another sweep. Each layer was bonded to the one below and eventually the completed object emerged.

Stereolithography is still in use but if you want to build from metal, you need a different system. Instead of a bath of liquid, you shake a thin layer of metal powder onto the floor of the printer and use a high-power laser or electron beam to liquefy certain areas. The powder melts and fuses, you shake a new layer of powder on top and repeat. Because the object is always surrounded by a deepening bed of metal powder, you don't need special struts to support the object as it builds. For decorative figurines, powder bed printers can even create objects in full colour. These use a plaster powder and a printer that combines ink and a glue binder. At **www.figureprints.com** you can have your character from the online role-playing game *World Of Warcraft* printed out in this way as your own full-colour memento. ▶



The Ultimaker 2 is hailed as one of the easiest-to-use 3D printers on the market


## 3D printers: the rivals

### MakerBot Replicator (5th generation)


***The pioneer***

MakerBot has been at the forefront of desktop 3D printing since 2009 and already is into its flagship product's fifth generation. This version is cloud and app enabled, letting you plan your model from your phone, tablet or laptop. The 100-micron layer resolution offers a spectacularly detailed print.

### Cube


***The toymaker***

Another market-leading 3D printer designed for the domestic market. The Cube lets you print in 16 different colours and objects up to 140 x 140 x 140mm (5.5 x 5.5 x 5.5in) in size making a 3D toy town a real possibility.

### Fortus 900mc


***The office worker***

The Fortus 900mc seems to be a great choice for businesses. It's large at a shade over $0.5m^3$ ($18ft^3$) but can still print with an accuracy of 0.09mm (0.0035in). It's been used to make ergonomic airline seats and gas tanks, among many other practical things.

### Foodini

***The private chef***

Ever got home from a hard day at work and wished you could just press a button for your dinner to be made? 3D printers like Foodini are making *Star Trek*-style replicators a reality. They aim to take the complicated, time-consuming preparation off our hands and can whip up both sweet and savoury snacks.

*"The real revolution has been the development of 3D printers cheap enough for the home user"*

## Home printing

All of these 3D printing techniques use machinery costing tens or hundreds of thousands of pounds. The real revolution has been the development of 3D printers cheap enough for the home user. To make your own 3D print, you have to start with a computer model of the object. This is a computerised drawing that specifies the precise positions of each corner, or vertex, and the radius and centre of every curve. You can create this in a computer-aided design (CAD) application or you can download an existing CAD file from sharing sites such as **www.thingiverse.com**.

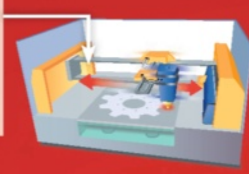
The 3D model allows you to visualise and edit the design but you can't print from it directly. It must first be digitally processed to break it down into a series of virtual horizontal slices that will form your object when they are stacked one on top of the other. These slices are then further processed into instructions that move the print head so that it creates each slice without any gaps or unwanted bridges. Home 3D printers use fused deposition modelling (FDM), which works rather like a hot glue gun. A spool of plastic wire or filament is fed to a heated print head that draws a line of melted plastic onto the object. By moving the print head horizontally past the stage with the model on it, the shape of a single slice is traced out. The stage then moves down by the height of a slice and the printer repeats for the next layer. The end result has a stepped effect, a bit like the pixels in a computer image, but modern 3D printers can work to a high enough resolution to make the steps almost invisible. ▶

## Printing with metal

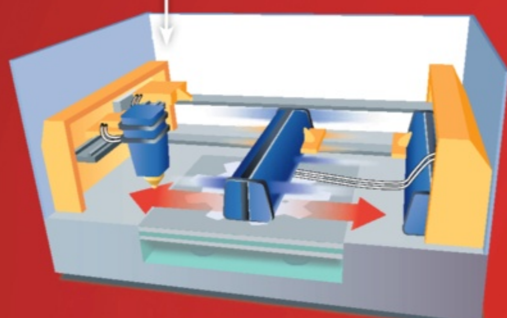
**Selective laser sintering is a 3D printing technique that can make things with steel or even titanium**

**1. 3D design**
The process begins with a digital model that is used to direct the movements of the 3D print head.

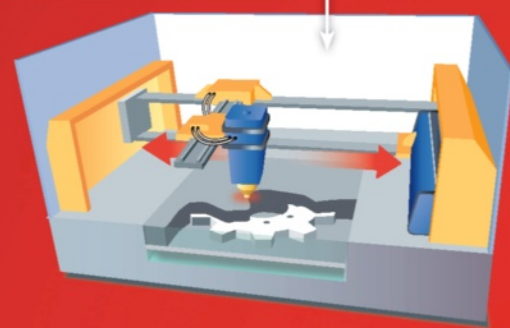
**2. Laser sintering**
The laser partially melts tiny grains of metal powder so that they stick together – a process known as sintering.



**3. New layers**
After each pass of the laser head, a new layer of metal powder is applied by a roller.

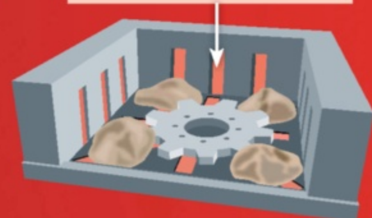


**4. Deep powder**
The process repeats, layer by layer. Delicate parts of the object are supported by the surrounding powder.

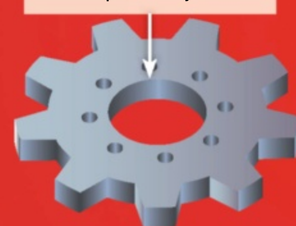


**5. Rough draft**
The object is removed from the loose powder. The basic shape is there but it's still quite porous and weak.

**6. Heat treating**
To strengthen it, the object is fired in a 2,000°C (3,632°F) furnace with other metals that melt and soak into the pores.

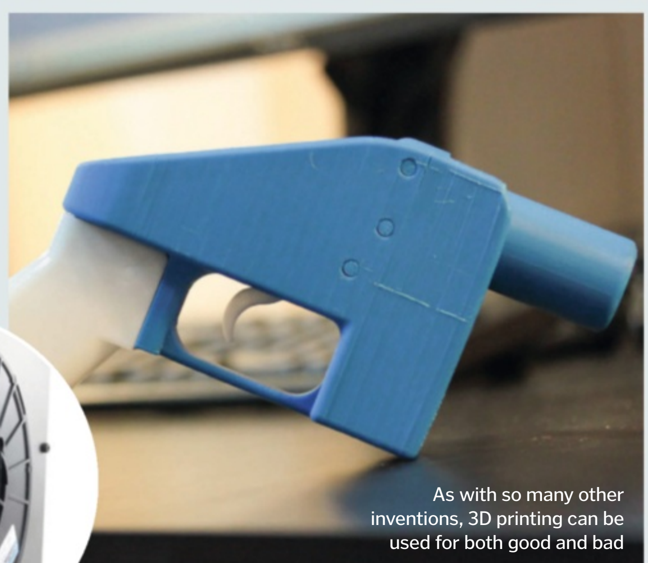


**7. Final touches**
Polishing and surface etching or coating provide a high-quality finish for the completed object.



## How expensive is additive printing?

A 1kg (2.2lb) spool of plastic filament to print objects in a single colour costs around £25 ($41). If you use this to print LEGO bricks, they will cost 5-20 pence (8-33 cents) in plastic. That's about a third of the cost of buying bricks directly from LEGO, but of course it doesn't take into account the cost of the printer itself, which is around £1,000 ($1,640) for a basic model. For a one-off, **www.shapeways.com** will let you upload a 3D design (or even design it directly on the website) and they will 3D print for you in your choice of materials. If you want an object printed in metal, this is the only economical method currently available to the home user. A silver ring, for example, can cost around £70-£100 ($115-164).



As with so many other inventions, 3D printing can be used for both good and bad

## 3D printing's dark side

3D printers can make almost anything, even guns. In 2012, the US libertarian organisation Defense Distributed published the files to print a plastic handgun called the Liberator. Since then, lots of different designs have emerged for plastic guns, and even plastic ammunition. These guns aren't very accurate and they don't last for many shots, but they are still lethal. Of course, it has always been possible to make your own gun at home, using easily available metalworking tools. However, 3D printing makes the process that much easier for the casual anarchist and attempts to outlaw the digital blueprints are unlikely to be effective.

# RECORD BREAKERS
## MAN-MADE ORGAN

# 4mm

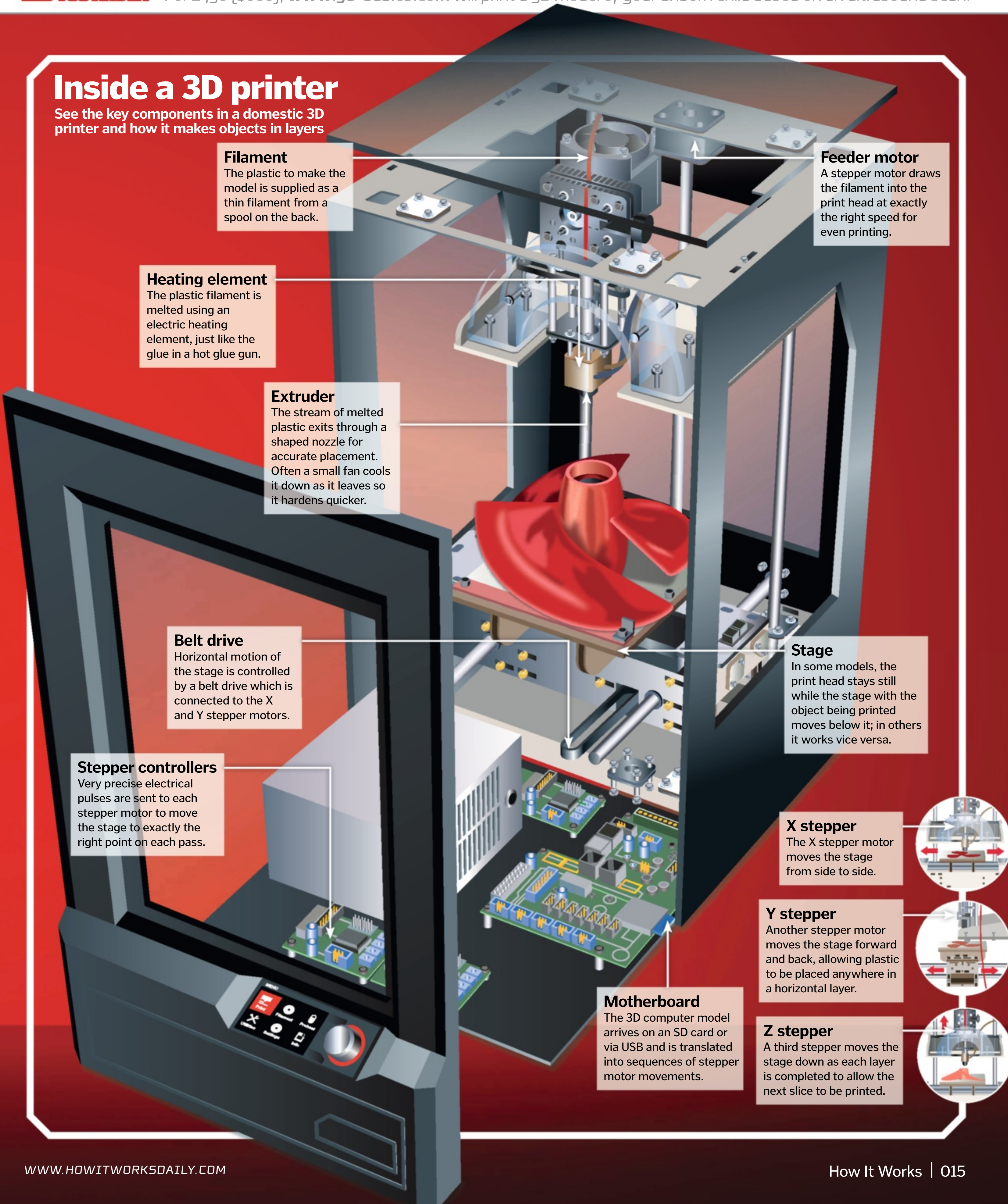
## SMALLEST ARTIFICIAL LIVER

US scientists used a 3D printer in 2013 to build a functioning human liver from living cells. Made up of 20 layers of hepatocyte cells, it measured just 4mm (0.16in) across and 0.5mm (0.02in) thick and survived for 40 days in the lab.

**DID YOU KNOW?** *For £490 ($800), **www.3d-babies.com** will print a 3D model of your unborn child based on an ultrasound scan!*

# Inside a 3D printer

**See the key components in a domestic 3D printer and how it makes objects in layers**



> "A Moon base could be 'printed' with a robot that uses microwaves to fuse the lunar soil"

## Printing tomorrow

The future of 3D printing will proceed on two fronts. At the industrial scale, new techniques will allow manufacturers to print with more and more materials. Electronic circuits can be built from an aerosol spray of powdered semiconductor materials. Optomec in Albuquerque, New Mexico, has developed wallpaper with LED lighting printed directly onto the pattern and British firm GKN Aerospace is printing physical buttons and switches using a piezoresistive ink that changes its electrical resistance when squeezed. In the home, though, the 3D-printing revolution will be just as dramatic. As prices continue to fall and systems get constantly easier to use, a home 3D printer could ultimately become as common as a regular inkjet 2D printer. This won't just be a way for us to express our own creativity though. It could eventually become a sort of teleporter, where it is quicker and cheaper to email someone the 3D plans for an object and let them print their own than to pop the original in the post.

### Medical

In 2012, an 83-year-old Belgian woman had an infected jawbone replaced with a custom-made 3D printed prosthetic. This technology is also used to make prosthetic limbs and other reconstructed organs (eg facial features) are close to reality. In the US, Align Technology makes 17 million 3D-printed, customised clear-plastic braces for children every year. 3D printers can even print customised drugs for patients by combining active ingredients with a binder to form tablets.

### Food

The website **www.cubify.com** sells cool sugar cubes, 3D printed into elegant geometric shapes. They are too delicate to ship outside California, but by the end of the year you'll be able to buy the printer that makes them. The ChefJet 3D from 3D Systems can also print in chocolate and is expected to cost under £3,000 ($5,000). Systems & Materials Research is developing a pizza printer for NASA, while Foodini is targeting domestic kitchens to make everyday food like burgers (pictured) and pasta without getting our hands dirty.

### Clothing & fashion

In 2013, Nike released the Vapor Laser Talon, a set of 3D-printed boot studs for football players, and Belgian company Kipling is soon launching a handbag that looks like a mesh of interlocking monkeys, printed with stereolithography. The Continuum N12 (above) is a ready-to-wear, 3D-printed bikini, made from thousands of interlocking nylon discs. Design studio Nervous System has gone one step further with an articulated dress that can be 3D printed while folded up.

# AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

A peek at the cheapest 3D printer around!

www.howitworksdaily.com

**DID YOU KNOW?** Bloc Party's frontman Kele Okereke released a limited-edition single on a 3D-printed vinyl record in 2013

## Transport

Right now the largest 3D printers in the world are printing titanium fuselage and wing parts for Chinese passenger airliners. But the technology isn't just for new planes. Ageing McDonnell Douglas MD-80 jets are still in use, but spare parts are hard to come by. Rather than ground its fleet due to leaky toilets, one US airline has 3D printed replacement plumbing. And while BMW cars are still made on traditional assembly lines (for now), 3D printers are being increasingly used to make custom tools.

## Space

NASA and Made In Space have been conducting trials during parabolic flights to test the effects of microgravity on 3D printing. This could soon be used onboard the ISS to manufacture spare parts. China uses 3D printing to create customised shuttle seats for their astronauts, and parts are also being printed for rocket engines (right). Architects A-ETC working with the Jet Propulsion Laboratory have proposed a Moon base that could be 'printed' with a robot that uses microwaves to fuse the lunar soil (see below).

## The cutting edge of printing

**Arjen Koppens, from technology innovator TNO in Holland, reveals his predictions for 3D printing**

**What are the drawbacks of metal 3D printing?**
**Arjen Koppens:** The accuracy and reliability is just not good enough yet. We had a part that took eight hours to print and we had to throw away the first five before the sixth one was okay. That's a week's work and a lot of wasted material.

**Is wastage worse in 3D printing than with traditional casting? Is this improving?**
**AK:** Yes, it's worse. It's a modelling problem. The thermal and mechanical stresses that build up in the chamber of the metal printer are really, really hard to completely understand. We are looking at ways to make this better with a simulation tool. It will tell you the settings to use to print it right on the first try… [by controlling] the laser power or the scan strategy or the [ambient] heat in the printing chamber.

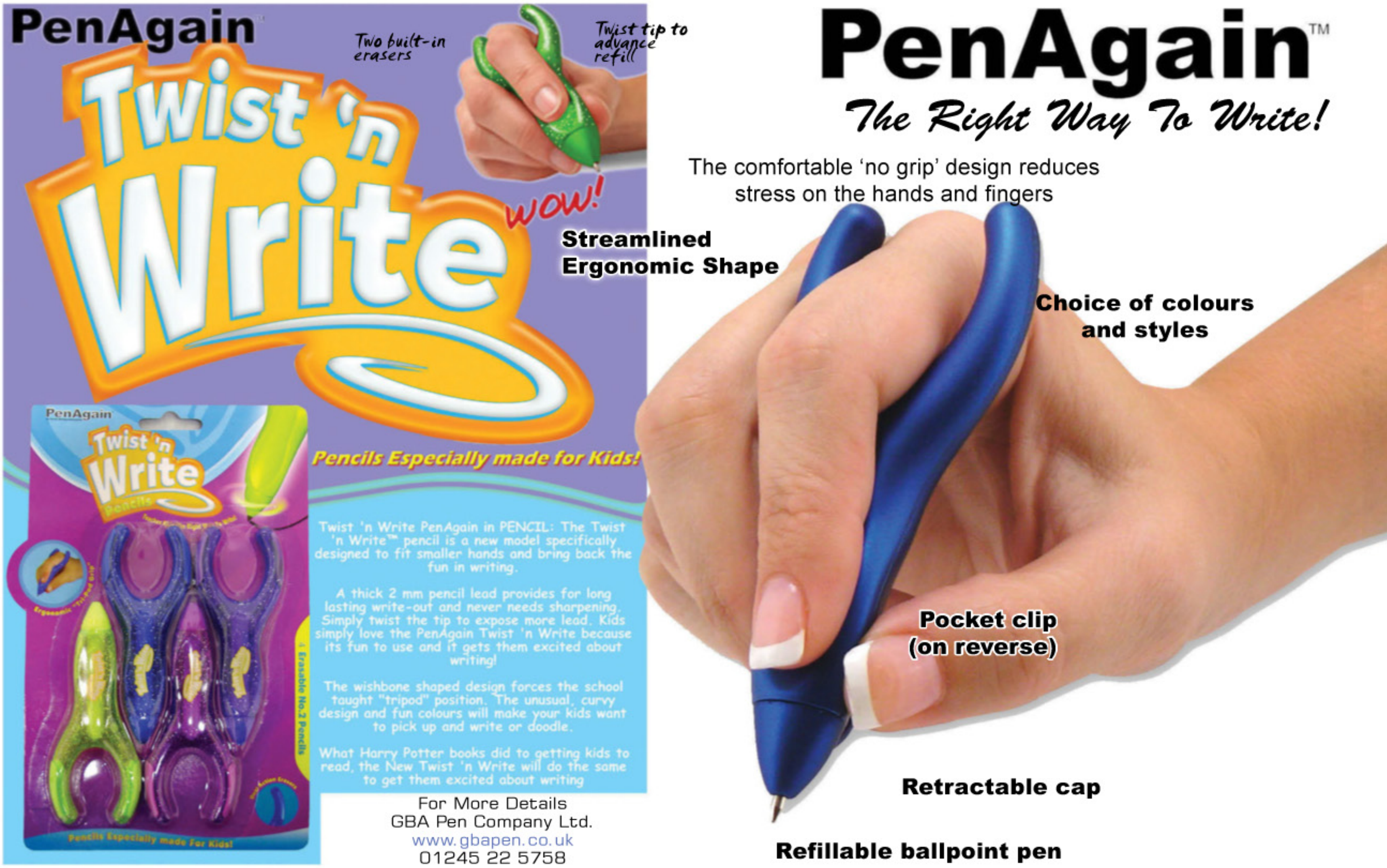
**What is the most exciting new technology for printing with plastic in your view?**
**AK:** It is inkjet technology. This prints with small droplets of the same [resin] used in stereolithography. So you don't work with a bath of the material but you selectively spray it and then directly cure [each layer] afterwards.

**Will this be available in the average home?**
**AK:** We have already seen very small tabletop stereolithography machines. They are not as cheap as the FDM machines, which you can now buy for less than £830 ($1,360) but the accuracy you can achieve is much better.

We have a machine that can go down to four microns, so you get a very smooth surface with very small details in it. We believe that stereolithography is the way forward because of the high resolution you can achieve.

**Is there anything that can't be 3D printed?**
**AK:** No. The only thing I don't see the sense in printing is very simple products, like a paperclip or a coffee cup. You can't reduce the weight and you can't print a shape that is more attractive or useful [than the existing ones].

© Natural Machines/Rex Features; NASA; BAE; Ian Moores Graphics; Getty; TNO.nl


PenAgain
Twist 'n Write
Two built-in erasers
Twist tip to advance refill
wow!
Pencils Especially made for Kids!
Twist 'n Write PenAgain in PENCIL: The Twist 'n Write™ pencil is a new model specifically designed to fit smaller hands and bring back the fun in writing.
A thick 2 mm pencil lead provides for long lasting write-out and never needs sharpening. Simply twist the tip to expose more lead. Kids simply love the PenAgain Twist 'n Write because its fun to use and it gets them excited about writing!
The wishbone shaped design forces the school taught "tripod" position. The unusual, curvy design and fun colours will make your kids want to pick up and write or doodle.
What Harry Potter books did to getting kids to read, the New Twist 'n Write will do the same to get them excited about writing
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The comfortable 'no grip' design reduces stress on the hands and fingers
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Raining
ALICIA KEYS
DIVA
Raining
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03:51 04:01
001/126
Reach new sonic heights
cocktail Audio X30
High Fidelity Storage, Streamer and Server
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richer SOUNDS
Superfi
audio T
All pre-recorded music is subject to copyright law

# 5 TOP FACTS
SEED STORAGE

**Global Seed Vault**
1 With around 800,000 seeds stashed away on remote Svalbard, this 'Doomsday vault' provides a high-security repository for worldwide seed banks to store backups.

**Millennium Seed Bank Partnership**
2 Prioritising plants at risk from climate change, this UK-based project aims to collect seeds from 25 per cent of the world's wild plants by 2020.

**Australian PlantBank**
3 With a focus on native plants, the Australian PlantBank houses seeds and cuttings from 4,669 different species – 260 of which are currently threatened or endangered.

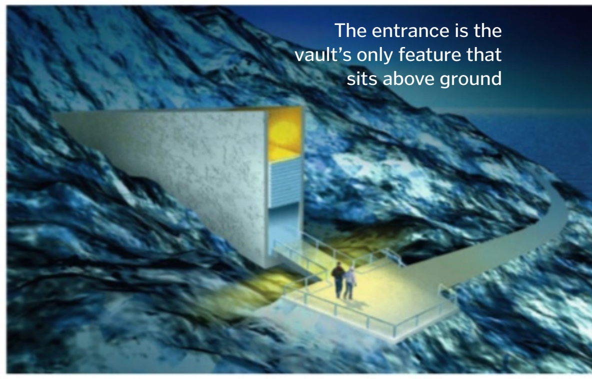
**Pavlovsk Experimental Station**
4 One of the first seed banks, established in 1926 by a Russian botanist, 90 per cent of the specimens it owns are found in no other collection.

**Navdanya**
5 With 65 community seed banks across India, this network supports local farmers by providing training and info on sustainable agriculture – plus access to 5,000 crop species.

**DID YOU KNOW?** *At the start of 2014, the Millennium Seed Bank Partnership had collected seeds from 80 countries*


The Global Seed Vault is intended as a 'safety deposit box' for the world's seeds


The Svalbard Global Seed Vault is buried in the permafrost of the Norwegian island


The entrance is the vault's only feature that sits above ground

# Why do we need seed banks?

## Providing a final lifeline for plants on the brink…

Plant biodiversity is shrinking alarmingly fast – some even predict that we will lose one species a day for the next 50 years. But for our planet's 100,000 endangered plant species, a handful of seeds stored in a special repository could make the difference between survival and extinction. Conserving flora is vital for our survival too, as a broad range of crop varieties is the best insurance policy against the impact of climate change, pests and natural disasters.

Since the Seventies, over 1,700 seed banks worldwide have taken on the challenge of cataloguing and stashing away seeds and cuttings from hundreds of thousands of species. Most have a particular focus, targeting crops, endangered species or a particular type of plant. These collections give researchers, breeders and farmers access to a wide range of plants, and if a variety is ever wiped out, it can be regenerated.

Once a species has been selected for banking, researchers collect its seeds in the field. Data is also recorded about the plant's environment so that it can be replanted in similar conditions if needed. Seeds are cleaned and then dried. Finally they are placed in airtight, moisture-impermeable containers and frozen. Under these conditions, the seeds can lie dormant for decades or even centuries. Their viability is assessed every five to ten years by defrosting and germinating a few in the lab. Once the seeds are approaching the end of their life span, they are grown to maturity to replenish the seed stock.


## What goes on at Svalbard?

**The Svalbard Global Seed Vault stores backup samples on behalf of seed banks all over the world. Luigi Guarino, senior scientist at the Global Crop Diversity Trust, tells us more…**

**How is Svalbard different from other banks?**
Svalbard is a safety deposit box rather than a current account. In a normal seed bank, farmers, breeders and researchers can get daily access to the seeds. In Svalbard, only the depositors ever have access to them, and they would only request them if something catastrophic happened to their own seed bank.

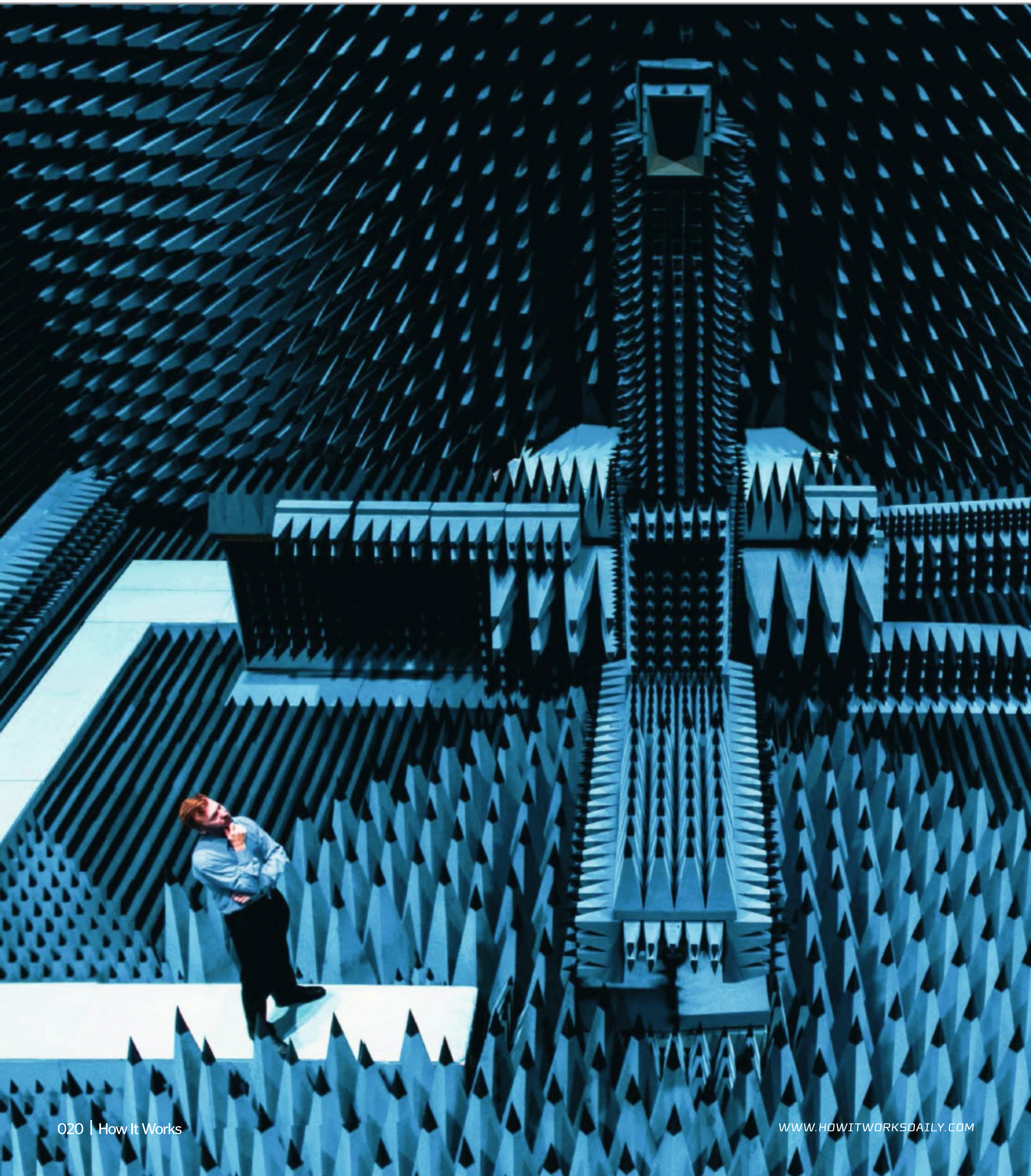
**Why might a seed bank lose its samples?**
Floods, fires, civil unrest, lack of money… all kinds of things can disrupt the normal operation of a seed bank. By putting your material in Svalbard you have a fail-safe mechanism to make sure that if something happens, you can always recover what you've lost.

**How was the location of the vault chosen?**
The key thing is that it's in the permafrost so it doesn't require as much energy to keep the temperature at -18°C [-0.4°F]. It's also in a part of the world that's very stable, both seismically and politically, and sufficiently above sea level to never worry about sea [flooding].

**Has anyone ever had to recover a species from Svalbard to date?**
No, not so far – and we hope they won't! The ideal situation is for normal seed banks around the world to operate effectively so they never need to have access to the material they've deposited in Svalbard.

© Mari Tefre/Svalbard Global Seed Vault; Global Crop Diversity Trust/Neil Palmer (CIAT)

*"Any reflected sound bounces off at an angle and hits an adjacent wedge, eliminating echo"*

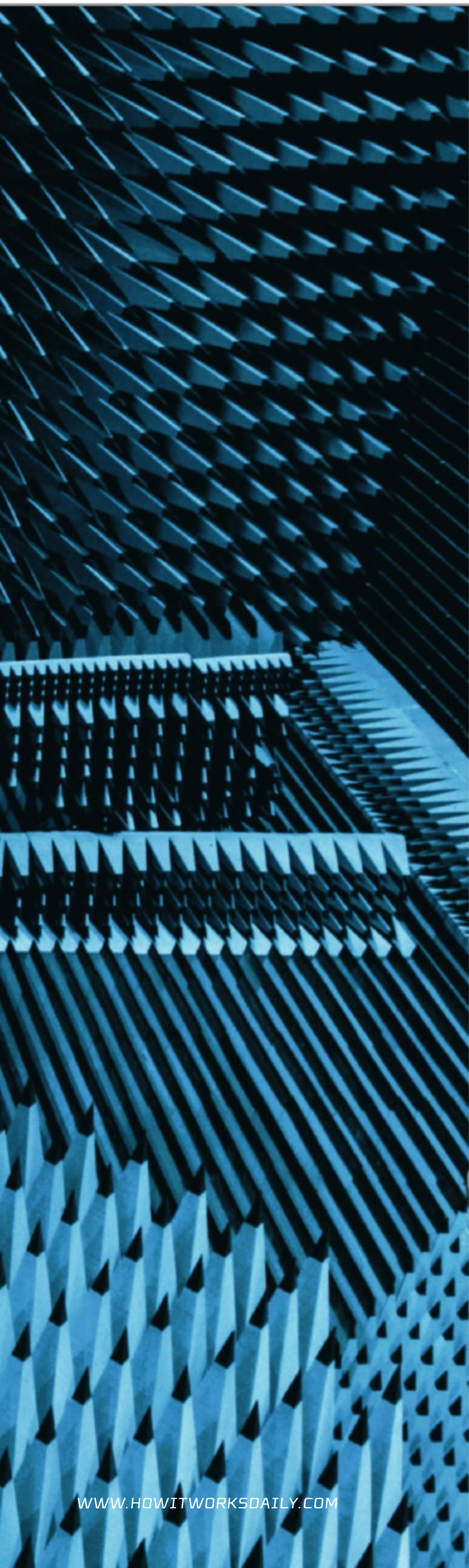


**99.99%**

**MOST SOUNDPROOF ROOM**

The anechoic test chamber at Orfield Laboratories in Minneapolis, USA, is so quiet it can induce hallucinations. It absorbs 99.99 per cent of sound. The longest anyone has spent inside is 45 minutes.

**DID YOU KNOW?** *The opposite is a reverberation room where hard, smooth, reflective walls intentionally bounce sound waves*



# The quietest rooms on Earth

## How do the walls in an anechoic chamber dissipate sound waves so all you hear is your own heartbeat?

Anechoic chambers are echoless rooms, designed to prevent the reflection of sound waves, but can work just as well at stopping electromagnetic radiation in its tracks. This enables accurate testing of acoustics and electrical equipment without interference from echoes.

To prevent the rebounding of audible sounds, anechoic chambers are lined with fibreglass wedges, covering the walls, floor and ceiling to create an uneven surface. Sound wave energy is absorbed by the fibreglass and transferred into the body of the wedge, where it dissipates. Any reflected sound bounces off at an angle and hits an adjacent wedge, eliminating echo.

Anechoic chambers can also prevent the reflection of electromagnetic radiation, including radio waves, and are used to test antennas and radar. These waves can't be absorbed by pure insulators or conductors, as they're ineffective at accepting energy. Therefore, the material lining radio anechoic chambers is designed to mix the properties of both insulators and conductors.

Rubberised insulating foam is impregnated with conductible metal, such as iron, and formed into mini pyramids. These capture and divert the electromagnetic waves, preventing them from reflecting back into the room. The pyramids' length is designed to match the frequency of the electromagnetic waves being tested, with longer pyramids for low frequencies and shorter ones for high frequencies.

Anechoic chambers are not just free from echoes, but often soundproof as well, and may be encased in concrete or suspended on shock absorbers to prevent noise entering from the outside. The same is true of radio anechoic chambers, which are protected from external sources of electromagnetic radiation by a Faraday cage – a mesh of conducting material that diverts any incoming electrical activity around the room without letting it in.

### The history of echoless rooms

First developed in the United States back in the Forties, wedge-lined anechoic chambers were originally used for acoustic testing, housed in concrete structures for soundproofing.

Modern chambers are similar in many ways, but the design has been refined to achieve more efficient loss of audible vibration, particularly at lower frequencies. They are also better insulated from external sources of interference, and are often mounted on sprung floors. This technique is also used in concert halls to protect them from any vibration in the building.

Radio anechoic chambers were developed in the Sixties and used the same principles to dissipate energy. To ensure that there are no unwanted emissions or reflections of electromagnetic radiation in the chamber, all equipment is insulated in nonconducting materials.

### ON THE MAP

**Anechoic chambers around the world**

**1** Orfield Laboratories, Minnesota, USA
**2** Benefield Anechoic Facility, California, USA
**3** University of Auckland, New Zealand
**4** Compact Payload Test Range, Noordwijk, the Netherlands
**5** University of Salford, UK


© SPL

"A new wave of technical innovation [promises] to offer gamers many new and exciting experiences"

# Xbox One vs PS4

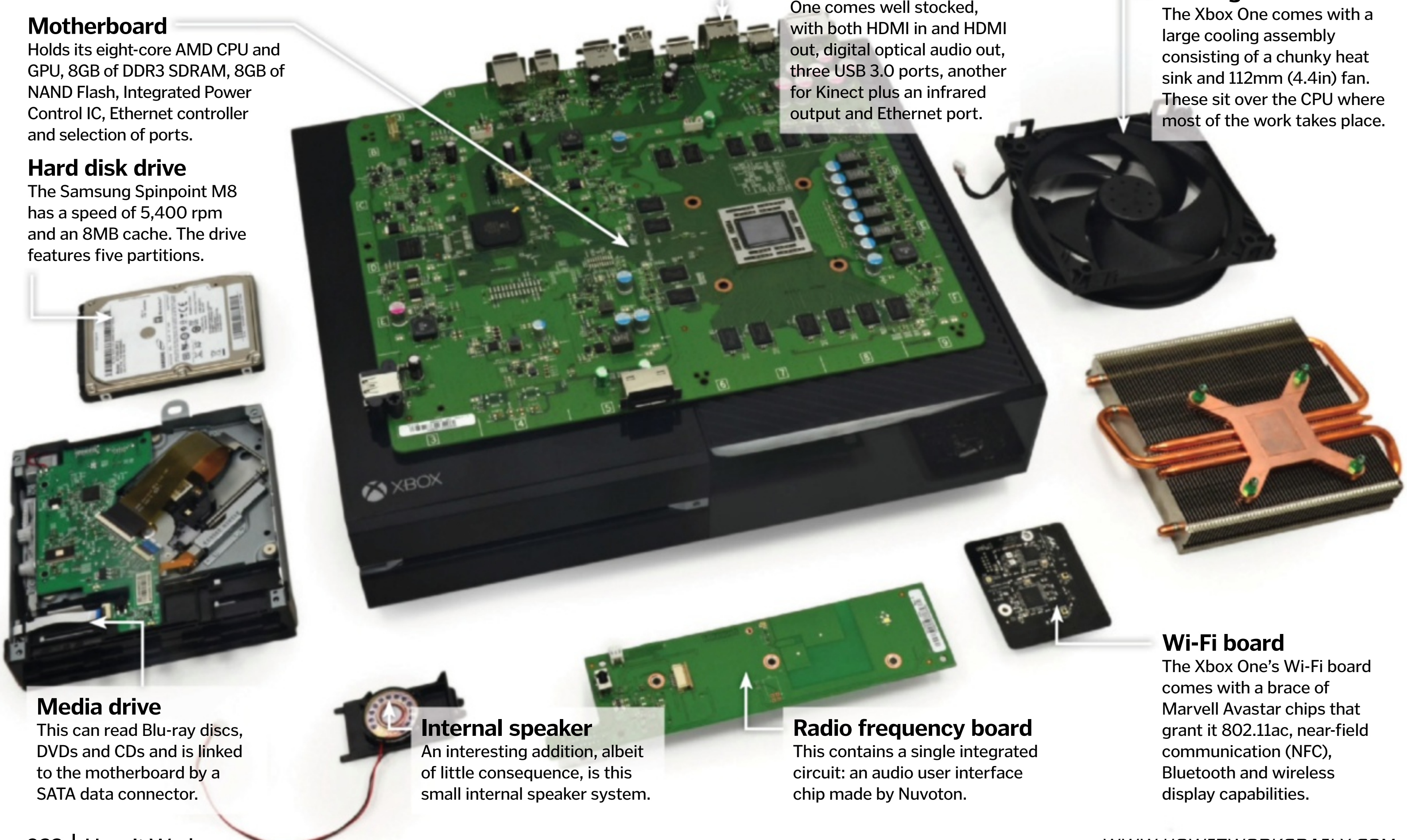
## The clash of the next-generation consoles is well underway – check out what technology lurks under the sleek exteriors of these gaming machines now

After what was seen by many as a brutally long seventh console generation, with the Xbox 360 and PS3 lasting a whopping eight years at the top of the market, Microsoft and Sony have finally released their successors in the form of the Xbox One and PS4. Simply put, they couldn't have come out at a better time, with the old consoles' hardware totally maxed out and a new wave of technical innovation promising to offer gamers many new and exciting experiences. From enhanced social functions such as in-game recording and online publishing software, through to high-definition graphics and on to revolutionary new voice and gesture control systems, the latest generation of games consoles has improved on its predecessors with a range of advanced computing technology.

As you would expect, a fierce battle is now underway to not only gain a dominant market share by the key players, but also an ideological one to capture the hearts and minds of the gaming community. Who will win has yet to be seen, but one thing is clear: the technology powering these gaming machines can now be scrutinised up close. Here we tear apart the Xbox One and PlayStation 4 to find out exactly what hardware powers them and see how they compare. Which will be the ultimate gaming system over the next decade? Only time will tell – or perhaps your mind will be made up once you've finished reading this article…

## Xbox One anatomy

**What technology has Microsoft packed into its new console?**



### Motherboard
Holds its eight-core AMD CPU and GPU, 8GB of DDR3 SDRAM, 8GB of NAND Flash, Integrated Power Control IC, Ethernet controller and selection of ports.

### Hard disk drive
The Samsung Spinpoint M8 has a speed of 5,400 rpm and an 8MB cache. The drive features five partitions.

### Ports
Connectivity-wise the Xbox One comes well stocked, with both HDMI in and HDMI out, digital optical audio out, three USB 3.0 ports, another for Kinect plus an infrared output and Ethernet port.

### Cooling
The Xbox One comes with a large cooling assembly consisting of a chunky heat sink and 112mm (4.4in) fan. These sit over the CPU where most of the work takes place.

### Media drive
This can read Blu-ray discs, DVDs and CDs and is linked to the motherboard by a SATA data connector.

### Internal speaker
An interesting addition, albeit of little consequence, is this small internal speaker system.

### Radio frequency board
This contains a single integrated circuit: an audio user interface chip made by Nuvoton.

### Wi-Fi board
The Xbox One's Wi-Fi board comes with a brace of Marvell Avastar chips that grant it 802.11ac, near-field communication (NFC), Bluetooth and wireless display capabilities.

# KEY DATES
## CONSOLE STORY

**1983**
Nintendo's first major console, Famicom – also known as the Nintendo Entertainment System (NES) – is released.

**1990**
Famicom's successor, the Super Famicom (SNES), is released and goes on to sell 49 million units worldwide.

**1998**
Sega releases the Dreamcast to much acclaim. But as the PS2 arrives, it doesn't fare well.

**2000**
The PlayStation 2 goes on to become the bestselling console of all time. With over 150 million units sold, that record still stands today.

**2013**
Sony releases the PS4 to critical acclaim and sales success. Microsoft's Xbox One follows shortly after.

**DID YOU KNOW?** *The Xbox One and PlayStation 4 represent the eighth generation of gaming consoles*



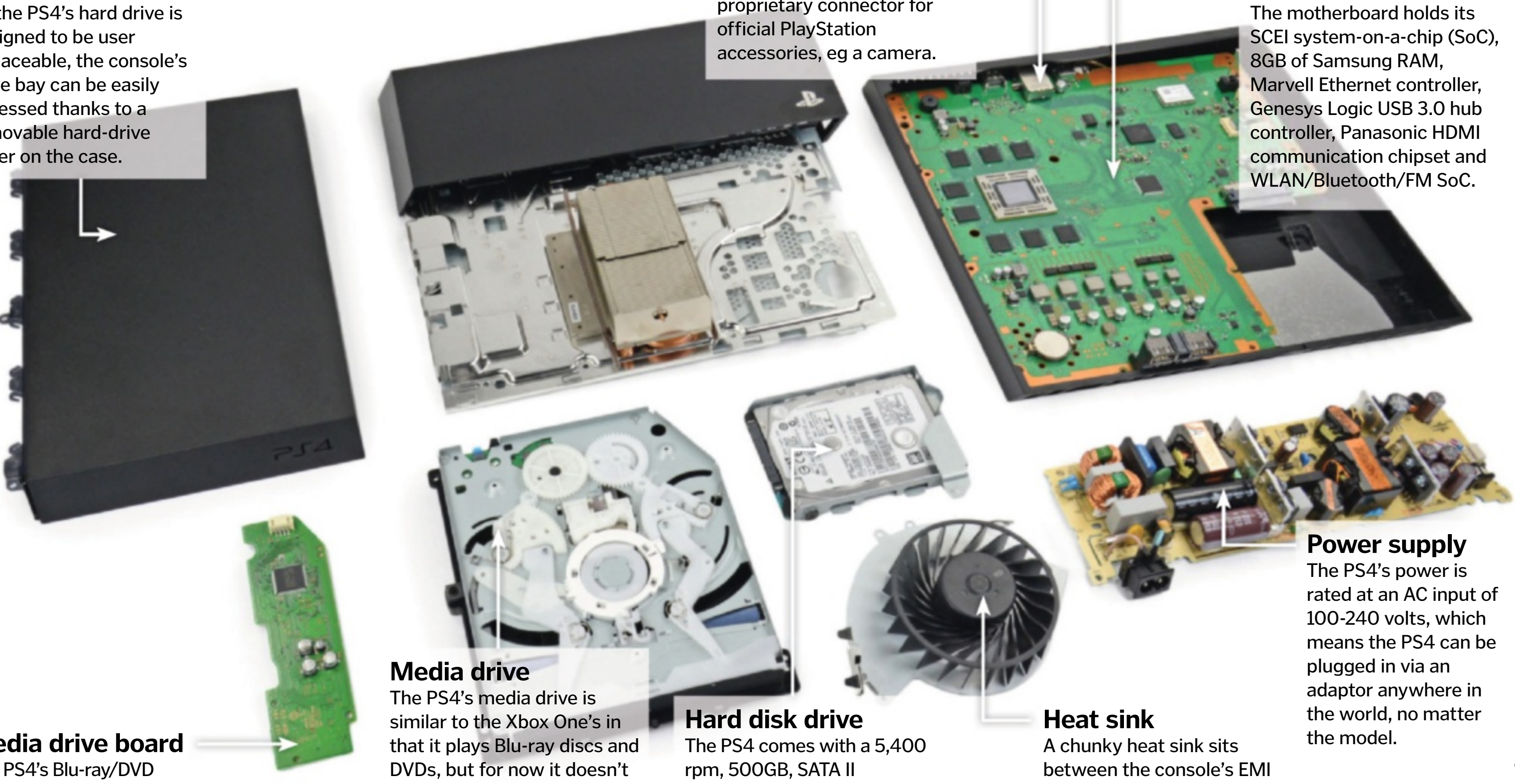
## Enter the steam punk

An interesting development has occurred largely under the radar in the PC gaming industry. Several manufacturers have announced they are going to release Steam Machines – but what are they? These small console-like PCs are designed to run STEAM, a digital game distribution platform that currently dominates PC gaming.

A key barrier to gaming on a PC has been the prohibitive costs and the technical know-how needed to get titles up and running. With Steam Machines, the PC gaming experience has been simplified and streamlined, with the systems very simple to activate and automatically booting into STEAM, where games can be purchased and played with ease. Whether or not Steam Machines will catch on is yet to be seen, but right now they are being considered a real mainstream contender to the major consoles.

# Inside the PS4

**How does the Sony console measure up to the Xbox One?**



### Casing
As the PS4's hard drive is designed to be user replaceable, the console's drive bay can be easily accessed thanks to a removable hard-drive cover on the case.

### Ports
The PS4 comes with two USB 3.0 ports, a digital optical audio out, an HDMI out, Ethernet and a proprietary connector for official PlayStation accessories, eg a camera.

### Motherboard
The motherboard holds its SCEI system-on-a-chip (SoC), 8GB of Samsung RAM, Marvell Ethernet controller, Genesys Logic USB 3.0 hub controller, Panasonic HDMI communication chipset and WLAN/Bluetooth/FM SoC.

### Power supply
The PS4's power is rated at an AC input of 100-240 volts, which means the PS4 can be plugged in via an adaptor anywhere in the world, no matter the model.

### Media drive board
The PS4's Blu-ray/DVD drive is controlled by a dedicated circuit board with four integrated circuits.

### Media drive
The PS4's media drive is similar to the Xbox One's in that it plays Blu-ray discs and DVDs, but for now it doesn't work with CDs; a software update is set to add this capability in the near future.

### Hard disk drive
The PS4 comes with a 5,400 rpm, 500GB, SATA II mechanical hard drive. It is a standard 6.4cm (2.5in) laptop size that can be replaced easily.

### Heat sink
A chunky heat sink sits between the console's EMI shield/CPU and a small curved fan, for moving heat away from the processor.

© iFixit.com; Getty

# Isambard Kingdom Brunel

## Though not always successful, Brunel's designs revolutionised transport, and he is now remembered as one of the greatest engineers of all time

Isambard Kingdom Brunel revolutionised rail and water transport not just in the UK but all around the world

> "SS Great Britain laid the foundations for a new era of transatlantic travel"

While an era of progress, the Industrial Revolution was also a time of trial and error. Those leading the way in technological advances attempted to make huge leaps forward, often resulting in failure, but sometimes incredible success. One of the greatest of the innovators of this time was Isambard Kingdom Brunel, born at the start of the 19th century. His father, Marc, was a French civil engineer, and encouraged his son to learn arithmetic, scale drawing and geometry. At 16, he became a watchmaker's apprentice.

In 1824 Marc was appointed chief engineer of a project to construct a tunnel under the River Thames. He hired his son as an assistant engineer, who later became resident engineer. The project was fraught with disaster, witnessing several incidents of flooding, as well as financial difficulties. At one point the operation was halted for several years and the tunnel bricked up. It was eventually opened in 1843 and is still in use today as part of the London Overground network.

The project transformed the young Brunel into a full-fledged engineer. In 1830 he entered a competition to design a bridge that would span across the River Avon in Bristol, and although rejected initially, he eventually persuaded the panel to appoint him as project engineer. Work on the Clifton Suspension Bridge commenced in June 1831, but just four months later the Queen Square riots drove investors away. Once again a project ground to a halt.

In 1833 Brunel was made chief engineer of the Great Western Railway, which would run from London to Bristol. It was then that he developed

## A life's work

**Brunel made his mark on history – but what were the defining moments in this innovator's career?**

**1806**
Isambard Kingdom Brunel is born in Portsmouth, UK, to French civil engineer Marc Isambard Brunel and Sophia Kingdom.

**1827**
Brunel is appointed resident engineer of the Thames Tunnel project in London, taking over from his father.

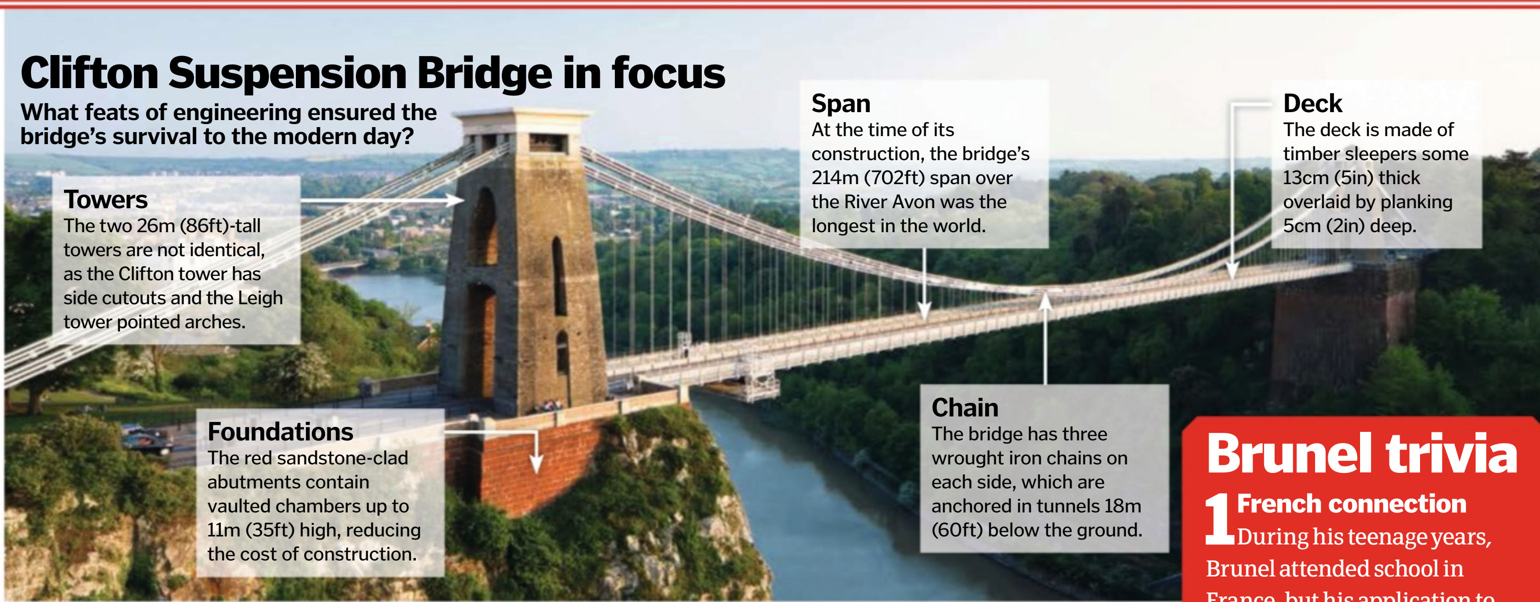
**1830**
He enters a competition to design a bridge to span the River Avon and is awarded first place.

**1831**
Work on the Clifton Suspension Bridge begins but financial difficulties bring the project to a halt.

**1833**
Brunel becomes chief engineer of the Great Western Railway, developing his idea for a wider track.

# Clifton Suspension Bridge in focus

**What feats of engineering ensured the bridge's survival to the modern day?**




## In their footsteps…

### Edward Harland

He formed Harland and Wolff Heavy Industries Ltd with Gustav Wolff in 1861, to build ocean liners. Harland built on Brunel's design, replacing wooden decks with iron ones for strength and giving the hulls a flatter bottom for capacity. In 1899, construction of the Oceanic began. At 215m (705ft) long, it was the first ship to exceed Brunel's Great Eastern.

### John Roebling

Born in the same year as Brunel, in 1840 Roebling was still unknown. In 1841 he began producing wire rope and in 1844 designed a replacement for a wooden aqueduct. The bridge was supported by a continuous cable of wires bound together, which is now the standard for bridge design. Roebling built many suspension bridges, including the Brooklyn Bridge.

## The big idea

The Clifton Suspension Bridge in Bristol spans 214m (702ft) between two 26.2m (86ft) towers, which then was the longest bridge span in the world. In its design of chains and rods, Brunel had made a near-perfect calculation of the minimal weight required to provide maximum strength. The abutments contain a honeycomb of chambers and tunnels, some of which are 11m (36ft) high, which reduced the cost of construction without compromising strength.

## Brunel trivia

**1 French connection**
During his teenage years, Brunel attended school in France, but his application to the renowned French engineering school École Polytechnique was rejected because he was a 'foreigner'.

**2 River party**
In 1827, after several incidents of flooding, Brunel held a lavish banquet inside the Thames Tunnel to help convince people that it was perfectly safe.

**3 Beating the competition**
Brunel's submission to the Clifton Bridge competition was initially rejected by the judge, Thomas Telford, who instead put forward his own design.

**4 Flip of a coin**
In 1843, while performing a magic trick for his children, a coin became lodged in his windpipe. To remove it, Brunel was strapped to a board and turned upside down.

**5 Lady with the lamp**
In 1855 he responded to a request from Florence Nightingale to design a new hospital to replace the unsanitary British Army Hospital in Scutari, Turkey, which he did successfully.

one of the most controversial ideas of his career – to use a 2.1-metre (seven-foot) gauge (distance between the tracks) rather than the standard 1.4-metre (4.6-foot) gauge. He believed that this would allow the trains to run at much higher speeds, as well as provide a more stable and comfortable journey. For the rest of his life the efficiency of this design was heavily contested.

But none could contest the efficiency of his Great Western Steamship, which transported passengers from Bristol to New York. It was thought a steamship would not be able to carry enough fuel for the trip and have room for cargo. However, it completed its maiden voyage in 15 days, with a third of its coal remaining. Brunel was also a fierce proponent of propeller-driven ships and incorporated a propeller on his second ship, SS Great Britain. Considered the first modern ocean-going ship, it was made of metal, powered by an engine rather than wind, and driven by a propeller rather than a paddle wheel. Indeed, this vessel laid the foundations for a new era of transatlantic travel.

Brunel's personal life was a series of ups and downs too. Many say the stress of the Great Western Railway led to his early death in 1859. Soon after Brunel's death it was decided that all railways in the country should revert to using the standard gauge. However, funds were also raised to complete the Clifton Bridge, which was finally opened five years after Brunel's death and is still in use to this day.

**1838**
The Great Western Steamship sails from Bristol to New York in just 15 days.

**1843**
The Thames Tunnel is opened to the public and the propeller-driven SS Great Britain is launched.

**1852**
Brunel's design for Paddington Station is constructed.

**1859**
Brunel dies on 15 September, ten days after suffering a stroke.

**1864**
The Clifton Suspension Bridge is finally completed as a tribute to Brunel by the Institute of Civil Engineers.

© Alamy; Thinkstock

# MEGAFLOODS

## Epic floods shaped our world but could they happen again today?

North-west America hosts some of the strangest and most spectacular landforms on our planet. Scarred into the black rock are giant channels carved out by water – the largest is the Grand Coulee in Washington at 97 kilometres (60 miles) long.

In 1922, geologist J Harlen Bretz began investigating how these channels formed. He initially attributed them to the slow action of rivers, but the more he looked into it, the more unusual landforms he discovered. Among them were piles of gravel some ten storeys high and hills shaped like boat prows.

These gargantuan features were best explained by water tearing through the landscape – an unimaginably massive megaflood. The prow-shaped hills pointed in the direction of flow, while the gravel was dropped when the floodwaters receded.

Bretz tracked the source of this colossal torrent – possibly the largest flood in history – to the glacial Lake Missoula. During the last ice age, this lake formed behind a 610-metre (2,000-foot)-tall wall of ice. When this dam failed, around 15,000 years ago, the lake emptied in just 48 hours and the waters carved the Grand Coulee. They left ripples, like those on a streambed, but a monstrous nine metres (30 feet) high. The process would repeat itself over the next 2,000 years, carving out more colossal landmarks in North America.

Lake Missoula might be the biggest known megaflood, but it's by no means the only one. Indeed, during the last 1.8 million years, at least 27 gigantic freshwater floods have shaped our planet, carrying more than 100,000 cubic metres (3.5 million cubic feet) of water every second – equivalent to over 30 Niagara Falls!

We know less about giant floods from further back in Earth's history. "As you go back in time, you don't have the landforms preserved," says ice-age geologist Professor Philip Gibbard.

Water escaping from natural dams or glaciers is responsible for many of the biggest floods, including Lake Missoula. Gibbard continues: "You get substantial flooding if a major dam floods and releases water."

Among them is the megaflood that turned Britain into an island around 450,000 to 200,000 years ago, when sea levels were lower than today. A gigantic lake formed in what is today's North Sea behind a chalk ridge that once connected Britain to France by land. When the lake punched through the natural dam, floodwaters gouged a huge valley into the English Channel seabed (see the thermal imagery on the opposite page).

Other massive floods occurred when sea levels rose after an arid spell. For instance, around 5.3 million years ago, Atlantic waters spilled into the dried-up Mediterranean; the ocean eroded a channel through the Strait of Gibraltar, filling the sea in as little as two years.

# 5 TOP FACTS
## FLOOD DEFENCES

**Maeslant Barrier**
1 Earth's largest movable storm surge barrier defends Netherlands' Rotterdam from floods. It spans a waterway 360m (1,200ft) across – as wide as the Eiffel Tower is tall.

**Thames Barrier**
2 This movable flood barrier is one of Earth's biggest and protects London against the North Sea. When raised, each of its ten steel gates is the height of a five-storey building.

**St Petersburg Dam**
3 The gigantic barrier includes 11 dams and is topped by a six-lane motorway. It was completed in 2011 after 300 years of almost yearly floods in the former Russian capital.

**West Closure Complex**
4 The world's biggest pump station – designed to blast floodwaters back out to sea – is among £8.5bn ($14bn) of works to protect New Orleans from future hurricanes.

**Delta Works**
5 Described by some as a 'wonder of the world', this huge series of 300 dams, sluices and storm surge barriers protects the low-lying Netherlands from the sea.

**DID YOU KNOW?** *Nearly half of flash-flood deaths occur in vehicles. Just 0.6m [2ft] of water can set a car afloat*

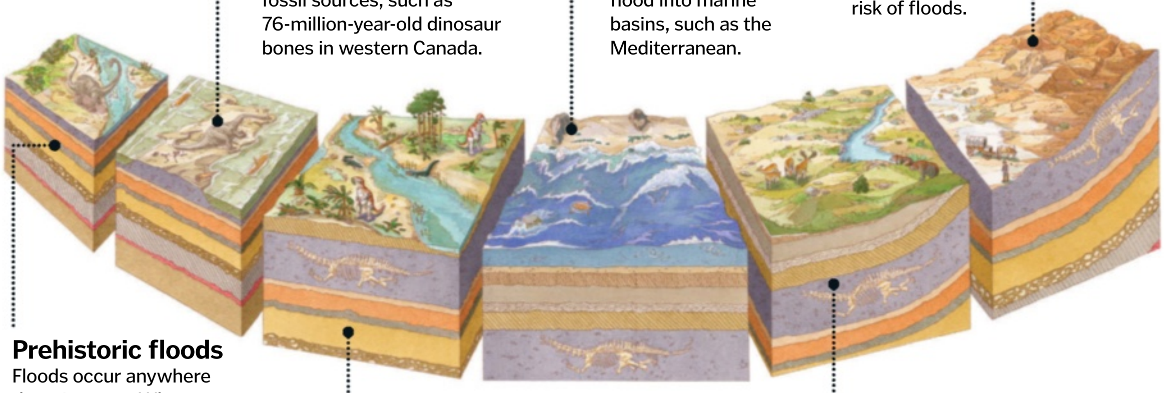
# Water world

**What role have ancient floods played in forming the planet we know today?**

**Dinosaur graveyard**
Ancient floods drowned prehistoric species, creating fossil sources, such as 76-million-year-old dinosaur bones in western Canada.

**Sea level rise**
Rising sea levels caused saltwater to flood into marine basins, such as the Mediterranean.

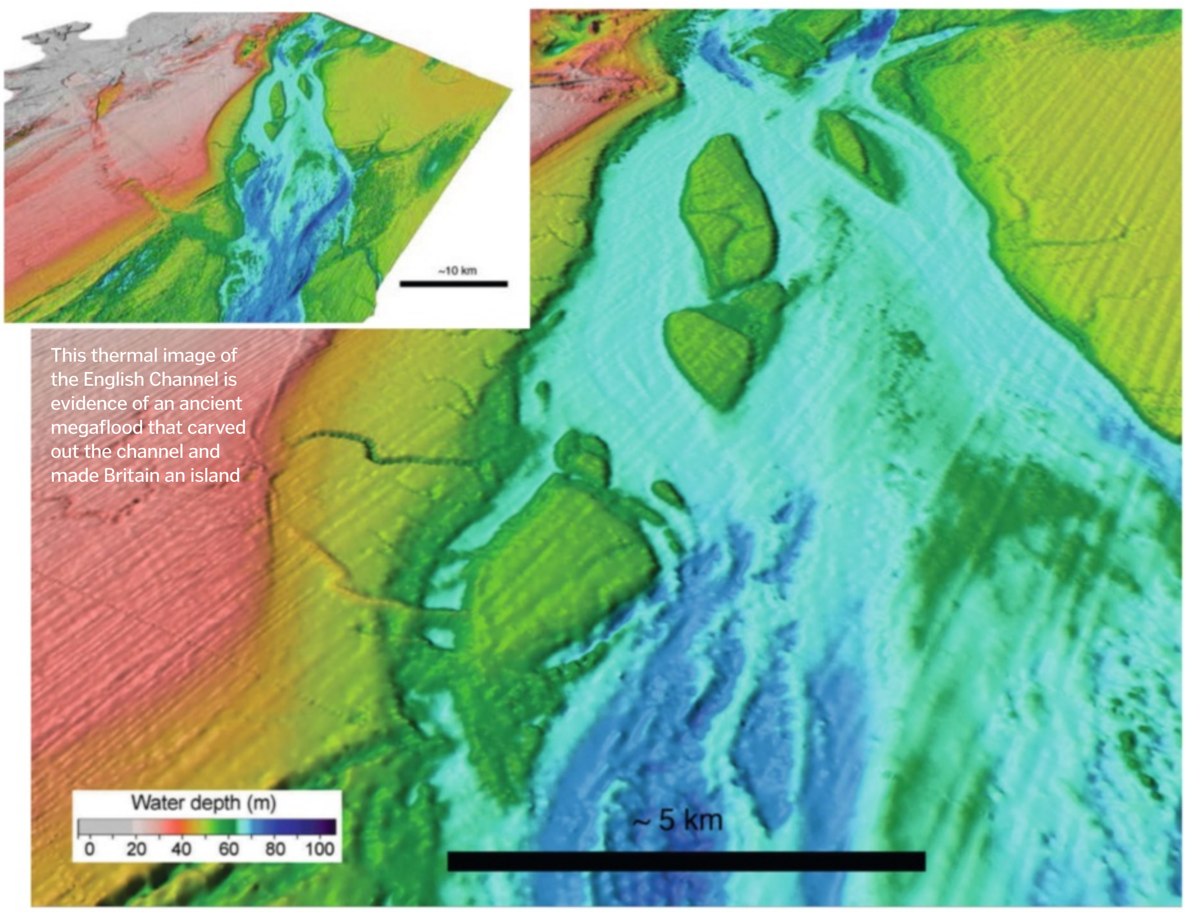
**Present day**
Humans build on flood plains, dam rivers and chop down trees – increasing the risk of floods.



**Prehistoric floods**
Floods occur anywhere there is water. When floodwaters retreat, nutrient-rich sediments are often left behind.

**Ancient sediments**
Evidence of prehistoric megafloods includes mineral deposits – such as microscopic zircon grains – dropped far downstream from their source.

**Ice ages**
Sea levels fell during ice ages. The ice formed natural dams across rivers, which collapsed to cause megafloods.




This thermal image of the English Channel is evidence of an ancient megaflood that carved out the channel and made Britain an island

## Biggest floods in history

**1 Altai Mountains, Asia**
What may possibly be the biggest flood of all time occurred around 12,000 years ago. Ice dams collapsed on two interconnected lakes, emptying them into the Mediterranean Sea in an estimated five hours.

**2 Wasilla, Alaska**
When the glacial Lake Atna in Alaska breached a natural ice dam around 17,000 years ago, the megaflood released as much as 1,400km³ (336mi³) of water – that's enough to cover the area of Washington DC in water 8km (5mi) deep!

**3 Bonneville flood, North America**
During a wet period 14,500 years ago, Lake Bonneville overflowed its basin. The floodwaters stripped soil, filled a 100m (330ft)-deep canyon to the brim and created immense and powerful waterfalls.

**4 Yarlung-Tsangpo Gorge, Tibet**
Gigantic lakes trapped in the Himalayas by ice dams helped erode this majestic gorge – which is possibly Earth's deepest. Evidence exists of several megafloods in the gorge during the last 2.5 million years.

**5 Black Sea deluge**
The biblical story of Noah and the great flood might well be based on a real historical event. Rising sea levels around 7,500 years ago may have flooded the Black Sea, destroying human settlements in the process.

> "Jökulhlaup, or glacier bursts, occur when a volcano erupts under an ice cap, eg the 1996 Vatnajökull eruption"

Megafloods can also have a massive impact on the climate. The Lake Agassiz flood, for example, is blamed for a cold spell 12,900 years ago that sent North America's large mammals, like the woolly mammoth, extinct. Floodwaters poured into the North Atlantic, interfering with the ocean circulation that brings warm water to the poles, known as the Gulf Stream.

Fortunately floods as large as Lake Agassiz or Missoula are unlikely to happen today. The biggest deluges were associated with giant ice sheets that swathed the northern hemisphere during the last ice ages. The ice released torrents of meltwater and trapped huge lakes behind ice dams, which gradually succumbed to global warming. Only the Greenland and Antarctic ice sheets, and a few ice caps, remain.

But that doesn't count megafloods out altogether. Among the 27 known big freshwater floods in the last 1.8 million years, eight occurred after 1900. According to Gibbard: "We could experience a megaflood today. Look no further than Iceland where we see jökulhlaup."

Jökulhlaup, or glacier bursts, occur when a volcano erupts under an ice cap, such as the 1996 Vatnajökull eruption in south-east Iceland. A torrent of meltwater flooded from beneath the ice, wiping out anything that stood in its way, including bridges, roads and power lines. It's estimated that peak flows reached 50,000 cubic metres (1.8 million cubic feet) of water per second in this massive jökulhlaup.

Another cause of giant floods, says Gibbard, is where "you have a volcanic lake, and the volcano erupts and breaches the barrier holding the water in the crater. You can get a deadly mudflow, sweeping away everything in its path." An example is Lake Taupo, New Zealand's largest lake, which flooded during an eruption some 1,800 years ago.

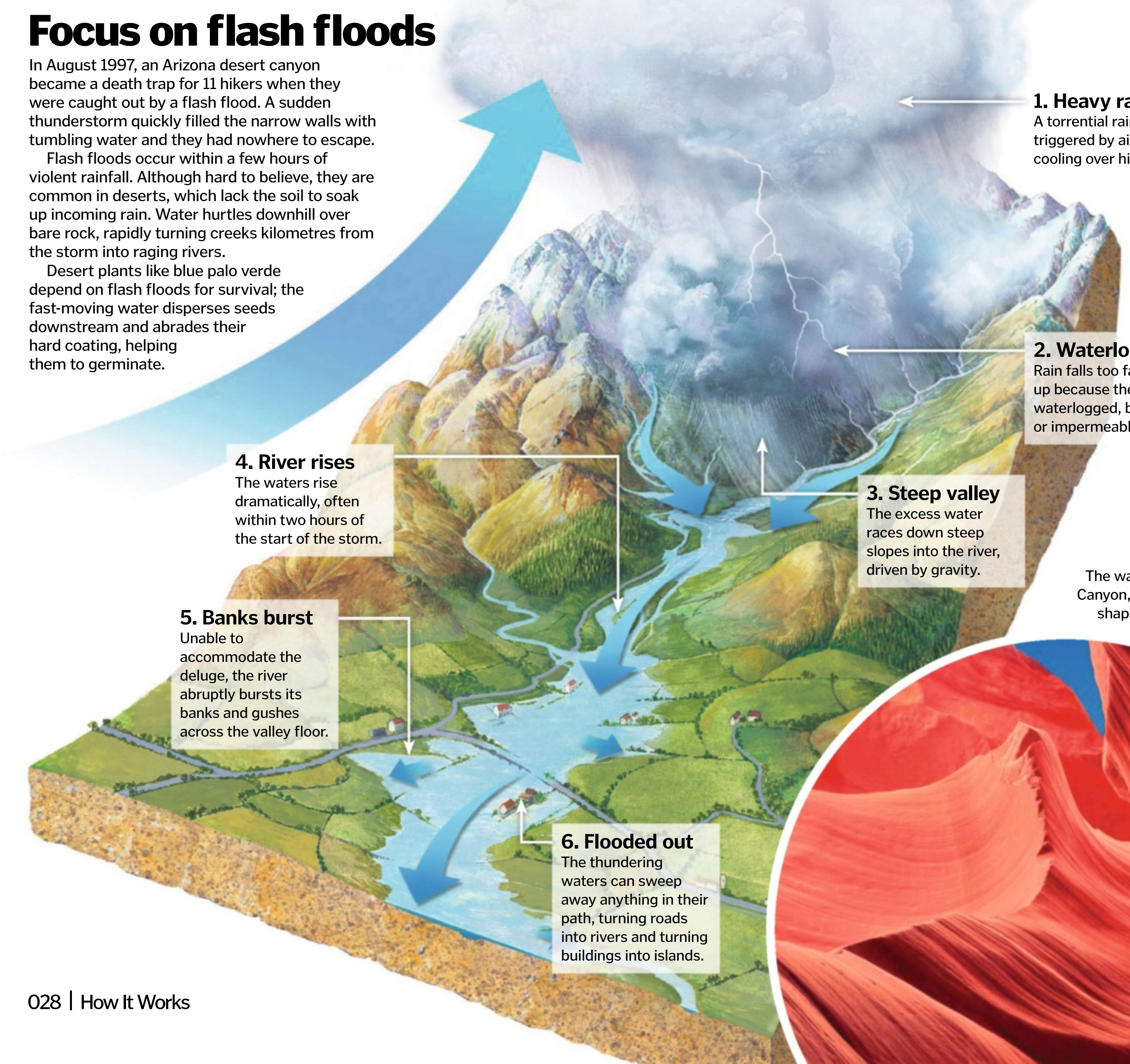
Debris from volcanoes can also block rivers. An eruption in Mount St Helens about 2,500 years ago caused Spirit Lake to empty catastrophically. More than 260,000 cubic metres (9.2 million cubic feet) of water per second flooded downstream. This was like a bathtub overflowing by comparison to Lake Missoula, though, which emptied at an incomprehensible 17 million cubic metres (600 million cubic feet) per second. Similar floods would have been likely after the 1980 eruption

## Focus on flash floods

In August 1997, an Arizona desert canyon became a death trap for 11 hikers when they were caught out by a flash flood. A sudden thunderstorm quickly filled the narrow walls with tumbling water and they had nowhere to escape.

Flash floods occur within a few hours of violent rainfall. Although hard to believe, they are common in deserts, which lack the soil to soak up incoming rain. Water hurtles downhill over bare rock, rapidly turning creeks kilometres from the storm into raging rivers.

Desert plants like blue palo verde depend on flash floods for survival; the fast-moving water disperses seeds downstream and abrades their hard coating, helping them to germinate.





The walls of Antelope Canyon, AZ, have been shaped by repeated flash floods


# AMAZING VIDEO!
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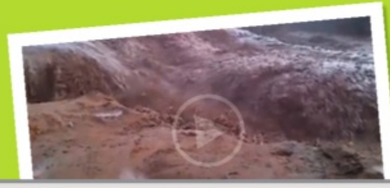
See a violent flash flood in Antelope Canyon!
www.howitworksdaily.com


**DID YOU KNOW?** *Floods are the deadliest natural disaster, responsible for an estimated 500,000 deaths between 1980 and 2009*

of Mount St Helen's if mitigation measures weren't undertaken and the lake had not been drained via a pipeline.

So how do these megafloods compare to more common flooding events, like we've seen in recent months? "They're orders of magnitude greater," explains Gibbard: "We're talking stuff that's incredibly dramatic. Much larger scale than conventional flooding of rivers."

Rivers bursting their banks are the most common cause of flooding today. Excessive rain or rapid snowmelt can overfill a river channel, causing water to spill out over low-lying land. Waterlogged or parched soil can also cause water levels to rise rapidly. Even a little rainfall cannot be soaked up by the ground so rush straight into the river, causing a flood.

Human activity – such as building hard tarmac roads – is making river flooding even worse, warns Gibbard. "The inevitable consequence of covering the landscape with impermeable materials is like wrapping it in a polythene bag. [More and more] water runs straight into our rivers."

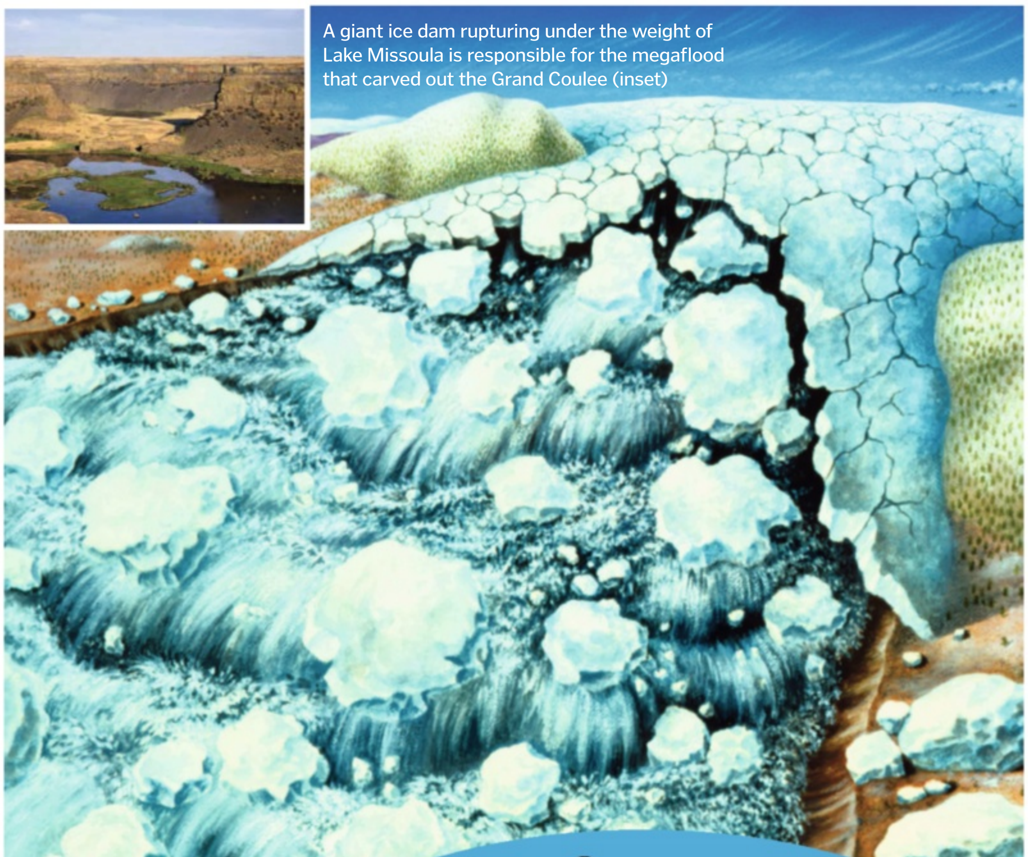
With sea levels predicted to rise dramatically this century – and climate change likely to boost storm power and frequency – the risk of coastal flooding is also on the rise.

Coastal flooding occurs when a storm blows seawater inland or when a tsunami – a giant wave usually generated by an oceanic earthquake – hits the shore.

The big question is, can we predict future megafloods? "Not easily," says Gibbard. "We know volcanoes erupt under ice caps in Iceland. People are trying to predict volcanic activity, but we're not there yet."

The next 'megaflood' might come from a man-made dam rupturing during an earthquake. Gibbard explains, "Anywhere where water is stored on less-than-firm ground might go. The sheer height of water behind those barrages must be enormous."

It's a real risk. Out of 85,000 American dams, over 4,400 are considered liable to failure. Among them is the Lake Isabella Dam in California. A strong earthquake could send around 700 million cubic metres (2.5 billion cubic feet) of water tumbling downriver. For now though the best we can do is never to underestimate the mighty power of water.


A giant ice dam rupturing under the weight of Lake Missoula is responsible for the megaflood that carved out the Grand Coulee (inset)

## ON THE MAP


**Flood-prone places around the globe**

**1** India
**2** Bangladesh
**3** Guangzhou, China
**4** New Orleans, USA
**5** The Netherlands
**6** Ho Chi Minh City, Vietnam


The Thames Barrier is an engineering marvel, protecting London from high tides

## How we defend against floods

An estimated 37 per cent of the world's population live within 100 kilometres (62 miles) of the coast – many in major cities like London, New York and Tokyo. They are at risk of flooding from unusually high tides and storm surges.

Many cities protect themselves from this threat with hi-tech barriers, dams or sluice gates. For example, the Thames Barrier downstream of London is a set of gates that lie flat on the riverbed when open. The gates rotate upright when a storm surge heads inland from the North Sea, or heavy rainfall raises the river level of the Thames enough that normal tides will cause flooding. Each gate can hold back 90,000 tons of water.

Other flood defence systems have permanent dams with sliding sluice gates to control water flow. The Oosterscheldedam in the Netherlands – the largest tidal barrier on Earth – is nine kilometres (5.6 miles) long and has 62 colossal gates; these raise to make the structure watertight.

New Orleans was flooded in Hurricane Katrina in 2005 – one of the deadliest storms in US history. Much of the city lies below sea level and depends on man-made embankments to keep out water. During the hurricane, these levees broke. The US Army is renovating the levees and building new defences, including a pumping station able to pump 540 cubic metres (19,000 cubic feet) of rainwater every second – enough to empty an Olympic-sized swimming pool in five seconds.

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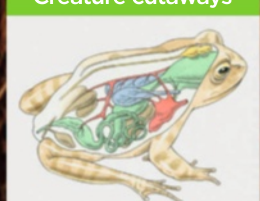


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## BIGGEST UNCUT DIAMOND

Earth's largest gem-quality diamond (3,106.75 carats) was discovered in the Cullinan Mine in 1905 and presented to King Edward VII. The British crown jewels incorporate two diamonds cut from this stone.

**DID YOU KNOW?** *Around 130 million carats of diamonds are mined annually – equal to about 26,000kg (57,300lb)*

# Diamond elevators

## Discover the volcanic pipes that bring these sparkling gems to light

In January 2014, a vivid blue diamond – a rare and coveted gem – was discovered in Cullinan in South Africa. It's among hundreds of stones produced by this prolific diamond mine, including the world's biggest-ever uncut gem.

Cullinan Mine is a kimberlite pipe – a carrot-shaped chimney of the blueish mineral kimberlite, which spans 320,000 square metres (3.4 million square feet) across at the surface. The majority of Earth's diamonds are found in these volcanic pipes – named after Kimberley, South Africa, where they were first discovered. Kimberlites are found only in cratons – ancient, geologically stable areas of continental crust often at the heart of tectonic plates.

Kimberlite pipes start life when molten rock – magma – in Earth's hot interior forces its way upward. Water in the magma dissolves silicate minerals in the surrounding continental rocks. Bubbles of carbon dioxide form, transforming the molten rocks into froth. When the foaming magma is forced through volcanic pipes, it behaves like water rocketing through a hosepipe, exploding through the crust in a violent eruption; at this stage it becomes lava.

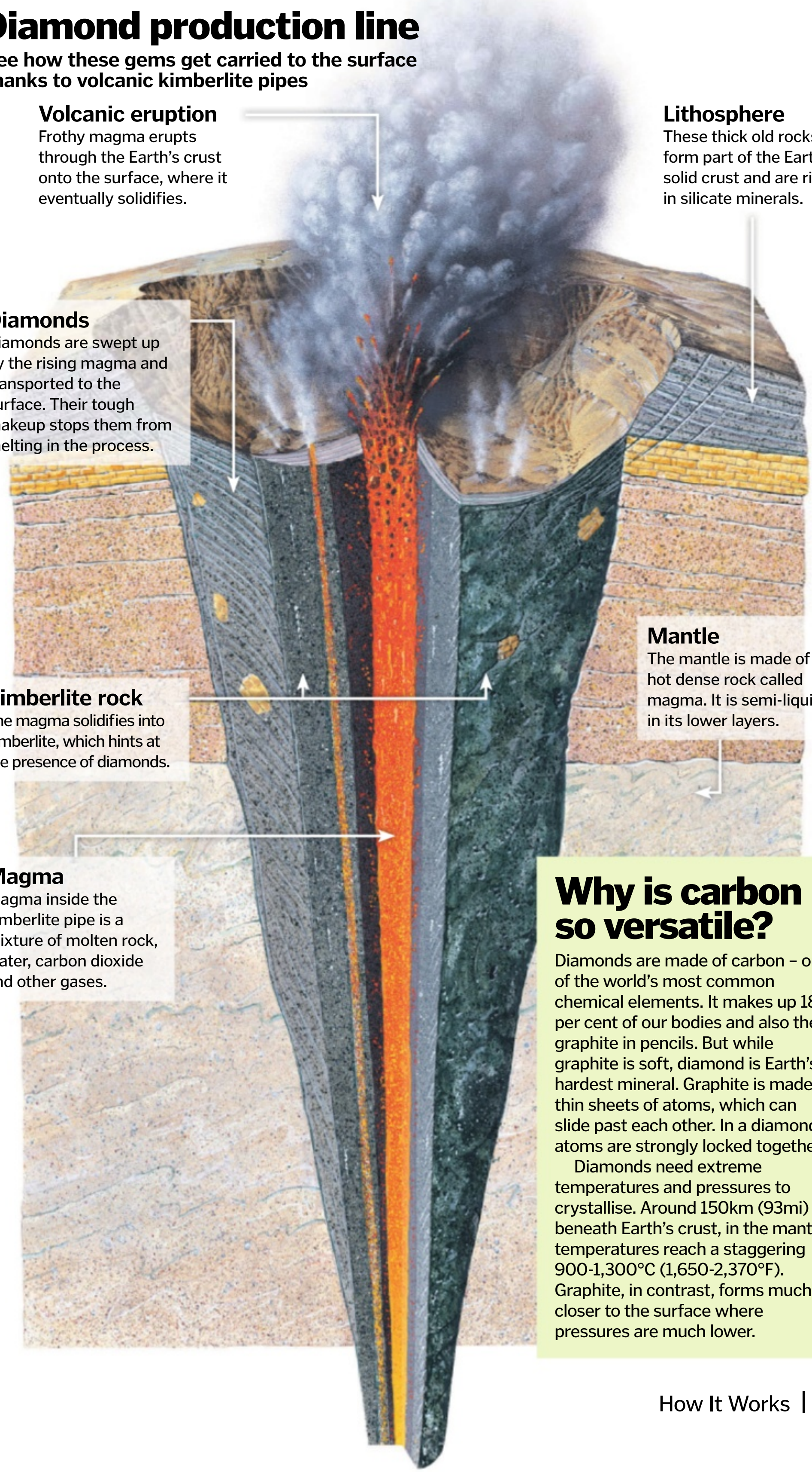
Diamonds form under immense heat and pressure deep inside the Earth and may be billions of years old. If the frothing magma sweeps through rocks rich in jewels, they are picked up and transported like people in an elevator. The diamonds travel quickly, which stops them decomposing into the mineral graphite during the superhot trip.

As the magma gradually cools, it solidifies into a kimberlite pipe, which may extend as much as 2.5 kilometres (1.6 miles) below the surface. The top layers of the pipe erode over millions of years, exposing layers of diamonds trapped in the rock.

The Cullinan Mine in South Africa is one of the planet's biggest diamond mines

## Diamond production line

**See how these gems get carried to the surface thanks to volcanic kimberlite pipes**




## Why is carbon so versatile?

Diamonds are made of carbon – one of the world's most common chemical elements. It makes up 18 per cent of our bodies and also the graphite in pencils. But while graphite is soft, diamond is Earth's hardest mineral. Graphite is made of thin sheets of atoms, which can slide past each other. In a diamond, atoms are strongly locked together.

Diamonds need extreme temperatures and pressures to crystallise. Around 150km (93mi) beneath Earth's crust, in the mantle, temperatures reach a staggering 900-1,300°C (1,650-2,370°F). Graphite, in contrast, forms much closer to the surface where pressures are much lower.

© SPL; Alamy

*"Sharks and rays are also capable of picking up the Earth's magnetic field"*

# Nature's satnavs

## How do some creatures use the Earth's magnetic field to find their way around?

In order to navigate when the sky is cloudy, humans use compasses, originally made from the magnetic material lodestone, or magnetite. This iron oxide is the most magnetic naturally occurring substance on the planet. Interestingly, several animals on Earth have evolved internal compasses that use the same stuff.

This navigational adaptation is ancient and the ability to detect a magnetic field can be observed in life forms as simple as bacteria. Magnetotactic bacteria produce chains of magnetite, or a similar iron oxide – greigite. These chains rotate within Earth's magnetic field and because the micro-organisms are so light, they rotate with them, like a compass needle. Using their internal compasses, the bacteria are prevented from being carried away from the narrow zones where conditions are optimal for their survival.

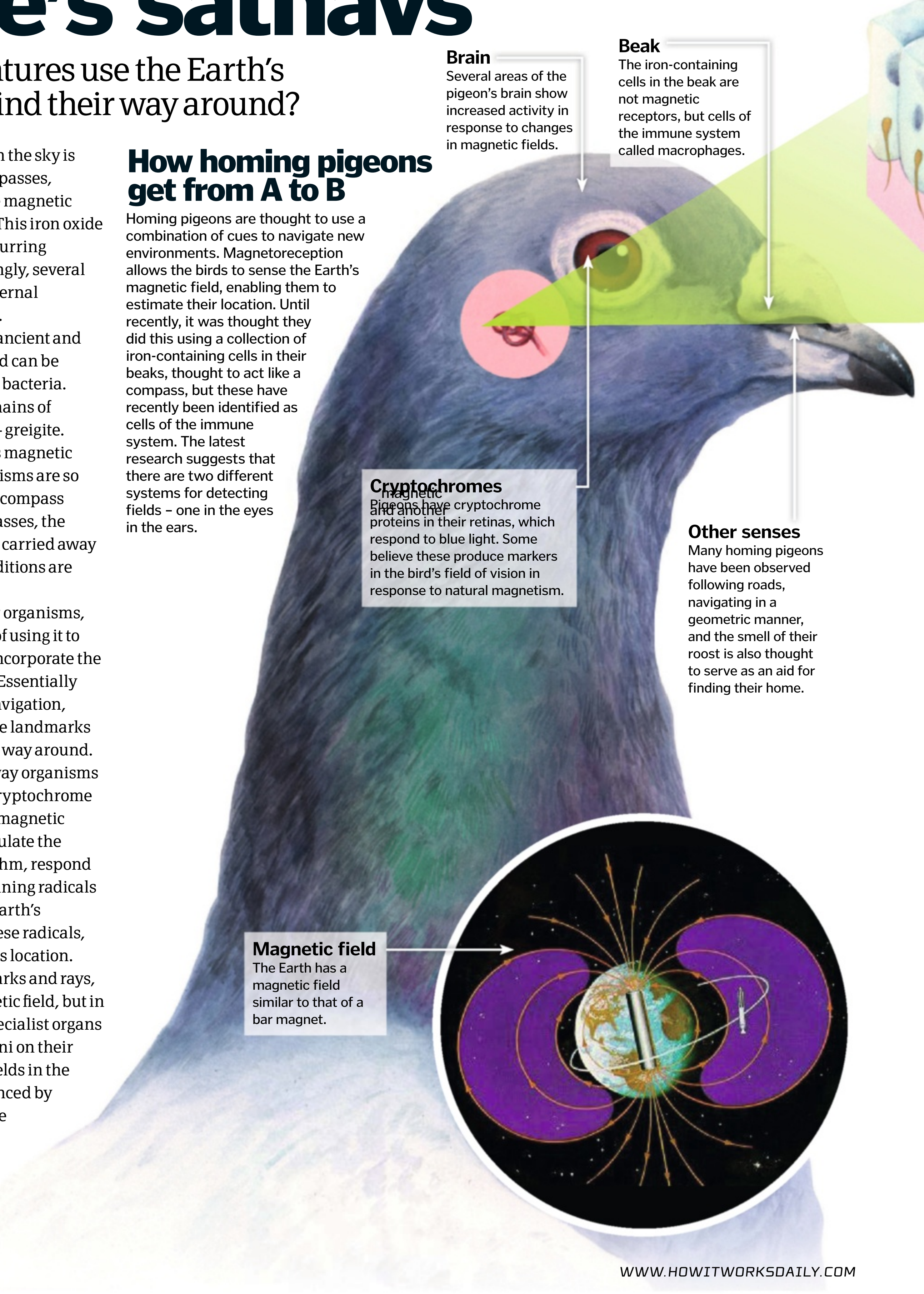
Magnetite is also found in larger organisms, like pigeons and fish, but instead of using it to turn like a compass needle, they incorporate the metal compound into nerve cells. Essentially this gives them a sixth sense for navigation, which they use with other cues like landmarks and the Sun's position to find their way around.

Magnetic metal is not the only way organisms detect magnetic fields; some use cryptochrome proteins, found in the eye, to 'see' magnetic fields. These cells, also used to regulate the sleep-wake cycle of circadian rhythm, respond to blue light and generate two spinning radicals – chemically reactive molecules. Earth's magnetic field alters the spin of these radicals, enabling the animal to establish its location.

Cartilaginous fish, including sharks and rays, can also pick up the Earth's magnetic field, but in a more indirect way. They have specialist organs known as the ampullae of Lorenzini on their face, which can detect electrical fields in the water. Oceanic currents are influenced by Earth's magnetic field and generate electrical signals, which can be picked up by the nerve cells, allowing the fish to orientate themselves.

### How homing pigeons get from A to B

Homing pigeons are thought to use a combination of cues to navigate new environments. Magnetoreception allows the birds to sense the Earth's magnetic field, enabling them to estimate their location. Until recently, it was thought they did this using a collection of iron-containing cells in their beaks, thought to act like a compass, but these have recently been identified as cells of the immune system. The latest research suggests that there are two different systems for detecting fields – one in the eyes in the ears.

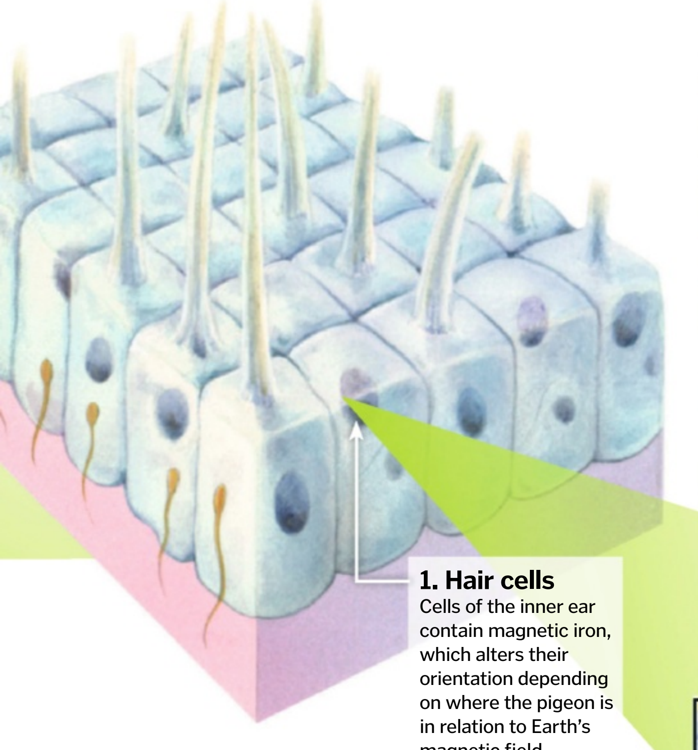


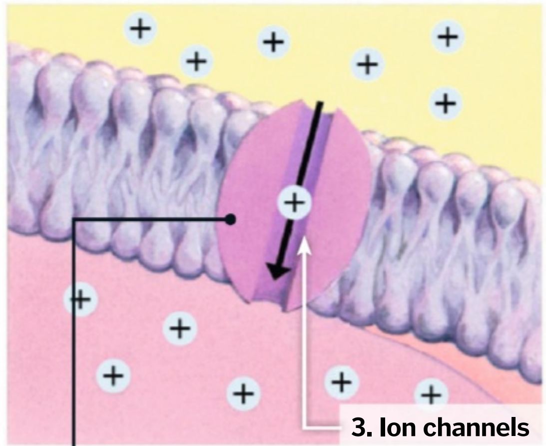
# $400K

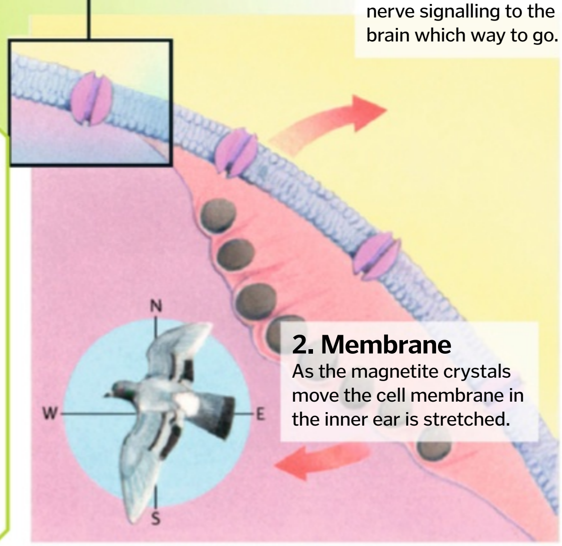
## MOST EXPENSIVE RACING PIGEON

The natural ability of some racing pigeons to find their way home is so prized that one bird – fittingly named Bolt after the sprinter – was sold for $400,000 at auction in 2013.

**DID YOU KNOW?** Magnetite is embedded in plastic to store information in magnetic storage devices, like floppy disks and hard drives




## Can people feel magnetic fields?

There is evidence that large mammals, even humans, might be sensitive to magnetic fields too. Magnetite has been detected in the bones of the human nose, and a magnetosensitive chryptochrome is found in the human eye. That said, our understanding of magnetoreception is not detailed enough to draw firm conclusions. Still, magnetic sensitivity has been experimented with in the body-modification community. This cosmetic technique uses a silicon-encased neodymium magnet implanted in the fingertip. Wearers can levitate paperclips and some report being able to feel the magnetic fields around electric wires and even being able to detect a break in the circuit.

Sharks use sense organs called ampullae of Lorenzini to detect electrical fields in the ocean, for hunting and navigation

## Top five magnetic organisms

### 1 Magnetotactic bacteria

These micro critters use magnetic crystals to align themselves within the Earth's magnetic field like a compass needle. The entire creature rotates relative to the Earth. A meteorite from Mars has been claimed to contain fossilised magnetotactic bacteria (pictured above), though this has been fiercely contested.

### 2 Sea turtle

Landmarks in the sea are few and far between, so turtles use the Earth's magnetic field to navigate back to their favoured feeding grounds, following long, predictable routes every year.

### 3 Fruit fly

The laboratory fly, Drosophila melanogaster, has a cryptochrome able to detect a magnetic field. It is often used as a model to test the magnetoreceptor genes from other species.

### 4 Pigeon

Homing pigeons have iron spheres in the hair cells of their inner ears, allowing them to use the Earth's magnetic field to navigate.

### 5 Trout

Around one in every 10,000 of the cells lining a trout's nose contains powerful magnetic material, which responds rapidly to changes in the external magnetic field.

© Ian Jackson/The Art Agency; Alamy; NASA; Thinkstock

"The best way for a plant to ensure plentiful light is to grow taller than its neighbours"

# Climbing plants explained

## Meet the plants that have developed some sneaky tactics in their quest for sunlight

Without sunlight few plants can photosynthesise in order to grow. A plant in deep shade is therefore starved of food. All plants have some mechanism of growing towards the light, like an animal going in search of food, but some 'cheat' in their quest to catch some rays.

The best way for a plant to ensure plentiful light for its leaves is to grow taller than its neighbours. To stand tall, a plant needs a strong, usually woody stem, but it takes a lot of energy to manufacture such a sturdy structure, so other plants use an alternative strategy. They have only flimsy stems, which require less energy to produce, but have developed ways of climbing or scrambling over their rivals to reach the light from above. They rarely harm the plant they are growing over, because if they killed it, they would lose the climbing frame taking them to the top.


Climbing plants have evolved to use other plants, rocks or man-made structures for support. Vines have flexible, soft stems, while lianas are tougher climbers with woody stems

### Five techniques plants use to get to the top…

**Hooks & thorns**
These help the floppy stems of scrambling or trailing plants to grapple onto surrounding vegetation and hold them firmly in place. Roses are a prime example of this.

**Twining stems**
Some climbers (eg honeysuckle) produce stems that twist in a spiral as they develop. When the stem makes contact with another plant, it twines around it for support.

**Twining leafstalks**
Other climbers (eg clematis) have leaves that are sensitive to contact. If they brush against other vegetation or a fence, the leafstalks wrap around it like grapples.

**Tendrils**
These are grasping or twining extensions from the leaves or leafstalks (like pictured above). Some tendrils even have adhesive pads at their tips (eg Virginia creeper).

**Aerial roots**
Growing from swollen nodes along stems and branches, some wrap around another plant, while others grow into the mortar of walls or under tree bark to anchor the plant in place (eg ivy).

# Secrets of peat

## How this organic material forms and why it has an impact on climate change

Peat forms in cool, wet places and is found all over the world. Bog mosses are the main peat formers. When they die, their remains rot slowly, because bacteria are not very active in cold, damp conditions. This slow decay releases humic acids, which restrict bacterial activity even more. These acids preserve plant material and the decomposed remains of mosses and associated plants are what become peat. New bog mosses grow through the peat, so it is self-sustaining. Anything that falls into the peat is preserved as well, eg excavated pollen grains can tell us which plants grew in the area hundreds of years ago.

Peat also locks up carbon from the atmosphere, helping to reduce greenhouse gases and slowing climate change. Extracting or burning peat releases that carbon and speeds up climate change.


Small-scale excavation of peat provides a useful fuel for local people, but large-scale extraction is unsustainable; peatlands are more valuable as wildlife habitats and carbon stores

© Thinkstock; Corbis

## HEAD 2 HEAD
**BIG BITES**

**1. BIG**

**Red-bellied piranha**
With a blunt face and projecting jaw, they're not classically beautiful, but the interlocking teeth are perfect for tearing off chunks of flesh.

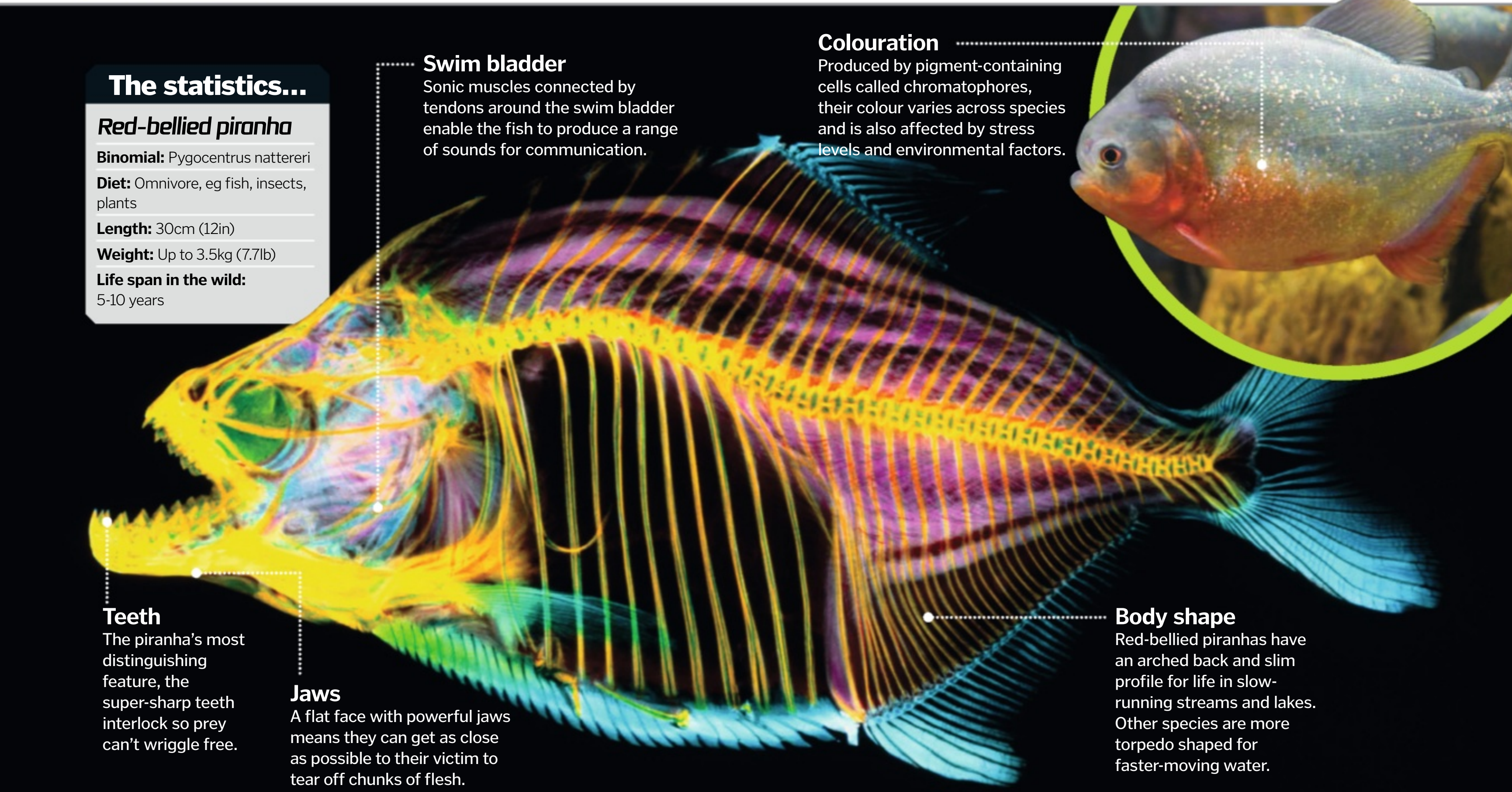
**2. BIGGER**

**Frogfish**
It uses a coloured lure to draw in prey. When they get close enough it sucks them into its huge mouth lined with needle-like gnashers in milliseconds.

**3. BIGGEST**

**Great white shark**
A great white has around 300 teeth, laid out in a conveyor-belt arrangement. The biggest can reach about 7.6cm (3in) in length.

**DID YOU KNOW?** *The name 'piranha' derives from the native Brazilian Tupi language for the words for fish ('pira') and tooth ('ranha')*




# The truth about piranhas

## They may be infamous for their teeth, but do piranhas deserve such a bad rep?

On the face of it, great white sharks and piranhas aren't all that similar. One lives in cool ocean waters, the other in South American waterways and lakes. One leads a solitary lifestyle, while the other prefers living in shoals. The biggest great whites can reach over six metres (20 feet) long while piranhas top out at 40 centimetres (16 inches). But they do have one thing in common: horror films have ruined their public image.

Of course, another feature these two fish share is what makes them notorious: an impressive set of gnashers. Unlike great whites, piranhas only have one row on each jaw, but that doesn't make them any less effective. Each tooth is razor sharp and triangular and they are laid out so they interlock like scissors. The jaw is also lined with very strong muscles for immense clamping power. Combined, this means they can grip on to their victims and shear off chunks of flesh with ease.

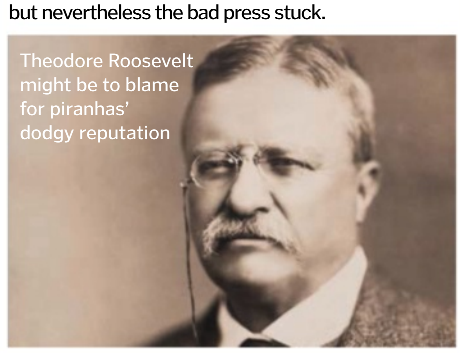
But just because they have the anatomical means isn't to say they're constantly on the prowl for people to reduce to bones. Recorded attacks on humans are rare – and if anything they are far more at risk from us, as they're a popular dish in their Amazonian habitat. They usually take on prey smaller than themselves – mainly other fish and insects – as well as scavenging on dead animals that wash downstream. That said, they are opportunists, so if a deer or tapir gets stuck in the mud while crossing a stream, a feeding frenzy could ensue.

Living in shoals not only offers safety in numbers, but also a greater chance of success when searching for food. They generally hunt at dawn or dusk, with a group of 20 to 30 individuals gathering in the shade of vegetation – though when water levels get low in summer the group can more than double in size.

The fish have demonstrated complex communication skills too, producing various 'barks' and 'croaks' by vibrating their swim bladders. These vocal displays seem to come in particularly handy for avoiding disputes within the group over mating rights and food.

### Amazonian assassin

The origins of the piranha's bloodthirsty reputation are thought to stem from US president Theodore Roosevelt, who visited Brazil in 1913. During his trip he reportedly witnessed the fish strip a cow to its skeleton in seconds. He talks about this experience in his book *Through The Brazilian Wilderness*, published the following year. He describes them as: '…the most ferocious fish in the world […] they will snap a finger off a hand incautiously trailed in the water; they mutilate swimmers […] they will rend and devour alive any wounded man or beast.' The accuracy of his account raises a number of doubts, but nevertheless the bad press stuck.



Theodore Roosevelt might be to blame for piranhas' dodgy reputation

© SPL; Thinkstock

*"Over 30,000 years, it has slowly dried up, leaving behind a huge level plain covered in a thick crust of salt"*

# World's largest salt flat

## The vast expanse known as Salar de Uyuni in Bolivia is a stunning sight to behold, but how did this massive salt flat develop?

When rainfall and melted snow drain down from mountains, they dissolve many minerals from the rocks. Generally, these are washed into the sea, adding to its salinity. Sometimes, however, the water drains into low-lying basins inland, forming salt lakes. If the climate is hot, with long dry seasons, water can evaporate from these lakes over centuries, leaving behind expanses of dried salt, called salt flats.

On the edge of the Andes Mountains of South America, the Altiplano is a vast plateau some 3,650 metres (12,000 feet) above sea level. At the top of the plateau lies a large, flat region, surrounded by higher land, in which a vast prehistoric salt lake formed. Over the last 30,000 years it has slowly dried up, leaving behind a huge level plain covered in a thick crust of salt, called Salar de Uyuni. This covers a staggering 10,582 square kilometres (4,086 square miles), making it Earth's biggest salt flat.

### Tour of Salar de Uyuni

**A varied landscape around the Salar offers a stark contrast to the white expanse of salt**


**Incahuasi Island**
A few dark 'islands' rise above the salt plain – the remains of ancient volcanoes. The largest, Incahuasi Island, is covered in spiny cacti.

**San Pedro de Quemes**
This village of about 570 inhabitants at the south-west corner of the flats is surrounded by high volcanic mountains, forming the border between Bolivia and Chile.

A view across the vast, flat Salar de Uyuni, toward the dormant Tunupa volcano

### Salt flats layer by layer

The salt crust of Salar de Uyuni is covered in cracks. It covers a layer of muddy soil saturated with brine, which wells up through the cracks. Beneath this are successively older bands of salt and sediments. As well as sodium chloride (salt), the brine contains the chlorides of potassium, lithium and magnesium. Lithium is valuable as a component of the batteries used in laptops, mobile phones and electric cars. 5 million tons of it could lie under the Salar, but the Bolivian government is cautious about developing it, fearing damage to the environment and local communities.

## 5 TOP FACTS
### SALAR DE UYUNI

**View from the Moon**
1 When Neil Armstrong and Buzz Aldrin first walked on the Moon on 20 July 1969, they spotted the vast white expanse of Uyuni, although at the time they mistook it for a glacier.

**Salty accommodation**
2 In 1995, a hotel was opened on the Uyuni salt flats built entirely from blocks of salt. It was closed in 2002 because of growing concerns about sewage pollution.

**Crumbling crust**
3 In places, the salt crust is a few tens of centimetres (1-2 feet) thick. Visitors have died from heat stroke when their vehicles became trapped by this crumbling crust.

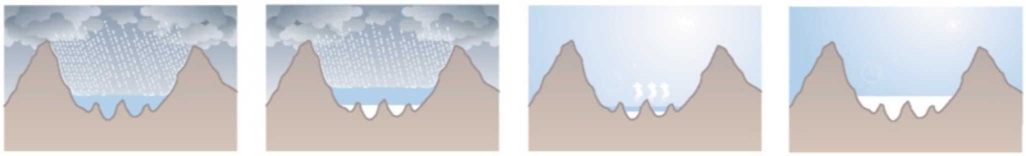
**Flat as a pancake**
4 Salar de Uyuni is the flattest place on Earth. It is so flat that scientists use its surface to calibrate the altimeters of ground-surveying satellites when they fly overhead.

**Flamingo food stop**
5 Brine shrimp survive dry periods as eggs and multiply rapidly when the saltwater returns. Three species of flamingos gather in the wet season to feast on the shrimp.

**DID YOU KNOW?** *Salar de Uyuni is estimated to contain 10bn tons of salt, but only around 25,000 tons is extracted annually*

# The vanishing lake

**See how Uyuni transformed from a huge lake to a salty plain over 30,000 years**

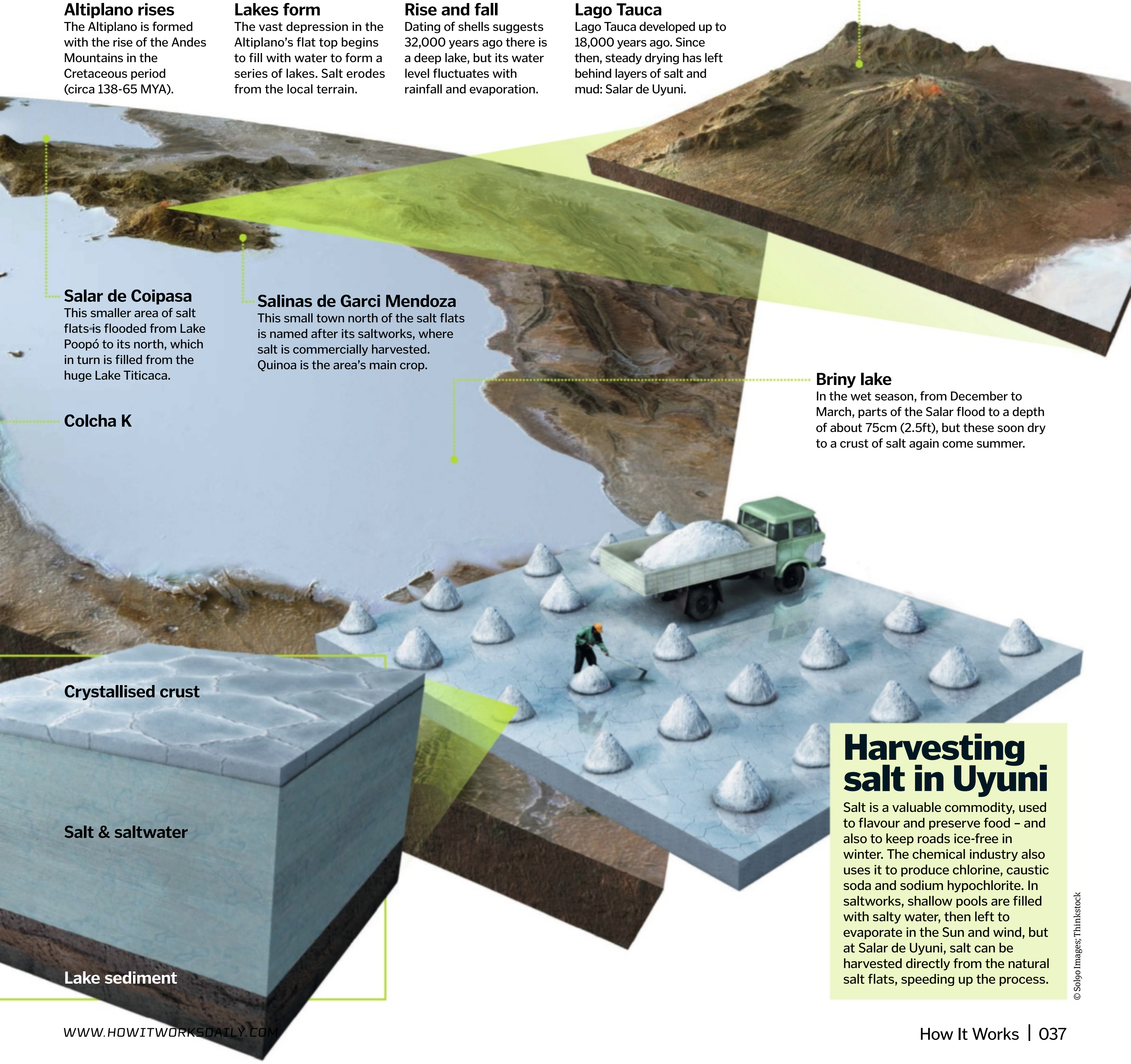


**Altiplano rises**
The Altiplano is formed with the rise of the Andes Mountains in the Cretaceous period (circa 138-65 MYA).

**Lakes form**
The vast depression in the Altiplano's flat top begins to fill with water to form a series of lakes. Salt erodes from the local terrain.

**Rise and fall**
Dating of shells suggests 32,000 years ago there is a deep lake, but its water level fluctuates with rainfall and evaporation.

**Lago Tauca**
Lago Tauca developed up to 18,000 years ago. Since then, steady drying has left behind layers of salt and mud: Salar de Uyuni.



**Volcán Tunupa**
The cone of an extinct volcano towers over the northern edge of the salt flats, beside the village of Tahua. It rises to 5,432m (17,822ft) above sea level.

**Salar de Coipasa**
This smaller area of salt flats is flooded from Lake Poopó to its north, which in turn is filled from the huge Lake Titicaca.

**Salinas de Garci Mendoza**
This small town north of the salt flats is named after its saltworks, where salt is commercially harvested. Quinoa is the area's main crop.

**Colcha K**

**Briny lake**
In the wet season, from December to March, parts of the Salar flood to a depth of about 75cm (2.5ft), but these soon dry to a crust of salt again come summer.

**Crystallised crust**

**Salt & saltwater**

**Lake sediment**

## Harvesting salt in Uyuni

Salt is a valuable commodity, used to flavour and preserve food – and also to keep roads ice-free in winter. The chemical industry also uses it to produce chlorine, caustic soda and sodium hypochlorite. In saltworks, shallow pools are filled with salty water, then left to evaporate in the Sun and wind, but at Salar de Uyuni, salt can be harvested directly from the natural salt flats, speeding up the process.

© Sol90 Images; Thinkstock

# Snow vehicles

## How machines have been engineered to tame even the most extreme winter terrain

In 1958, five years after Edmund Hillary and Sherpa Tenzing Norgay conquered Mount Everest, the relentless Kiwi explorer assisted Dr Vivian Fuchs in a daring land crossing of Antarctica. The expedition was the first to attempt Ernest Shackleton's failed 1914 transantarctic journey, one of the most harrowing survival stories in modern exploration history. Fuchs and his team traversed some of the most impassable terrain on Earth – littered with treacherous crevasses and ice-capped mountain ranges – to cross the whole of the frozen continent, some 3,473 kilometres (2,158 miles), in 99 days. But Fuchs, who was immediately knighted for his achievement, had an advantage over Shackleton and his stranded compatriots: a Sno-Cat. Even better, he had four of them.

The Sno-Cat was invented in the Forties by American EM Tucker, who for decades dreamed of a tracked snow vehicle capable of crossing the deepest snow and roughest ice. Modern Sno-Cats maintain Tucker's 1958 design for the transantarctic expedition: four independent tracks, each swivel-mounted on the drive axle to maintain firm contact with the ground over uneven terrain. In addition to old-school steel tracks, today's Sno-Cats include the option of all-rubber tracks that offer tremendous traction and longer service life. Sno-Cats remain some of the only vehicles in the world capable of reaching Arctic mining rigs and attempting deep-powder search-and-rescue missions.

The Sno-Cat is the master of traction, the greatest engineering challenge to ice and snow transport. To provide traction on slick surfaces, you need what engineers call 'bite'. The hundreds of steel or rubber teeth on a Sno-Cat or snowmobile track serve as multiple biting edges. Each edge is angled and positioned to provide a ▶

Vivian Fuchs (above) at the South Pole with his Sno-Cat

# 125.6m

## WORLD'S LONGEST SNOWMOBILE JUMP

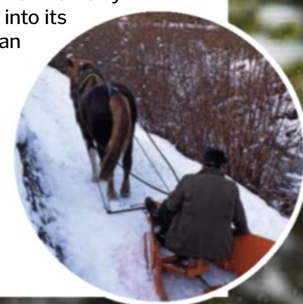
In 2011, American snowmobiler Levi LaVallee broke his own world record on a snow-free ramp in San Diego, CA, to cover 125.6m (412ft). He jumped simultaneously with a motorbike, which 'only' flew for 115m (378ft).

DID YOU KNOW? Champion snowshoe racers can complete a 10km (6.2mi) course in under an hour

Rotary snow ploughs can be fitted to the front of trains to clear snow-covered tracks

## Ploughs in focus

The first snow ploughs were horse-drawn sleighs mounted with an iron or wooden wedge (see below right). Today, ploughs are engineered for speed and efficiency. Truck-mounted ploughs feature hydraulic arms to adjust for blade height, discharge direction and road pressure. A recent innovation is to pair the conventional front plough with a second side-mounted blade that creates a wider plough path and ejects snow farther off the road. The first rotary snowblowers were invented in the late-19th century to clear railroad tracks impassable with a traditional wedge plough. The rotary snowblower works by scooping snow into its giant rotating fan blades – each around two metres (6.6 feet) long – which force the snow upward through an exhaust chute.




Snowmobiles combine power, traction and agility for traversing through all kinds of snow and ice

## How snowmobiles combat the snow

**The 2014 Yamaha SR Viper sports power, precision handling and comfort**

**1 Tracks**
Called lugs, the tracks' teeth are angled for maximum bite in both hard-packed snow and powder.

**2 Skis**
Plastic trail skis are wide and stiff with a ridge along the length of the keel for greater traction during turns.

**3 Shocks**
Gas shocks with coil springs plant skis firmly on the snow surface, even in bumpy conditions.

**4 Brakes**
The hydraulic braking system is activated at the handlebars to clamp down on a 20cm (8in) rotor.

**5 Engine**
The muscle of the Yamaha SR Viper is an electric-start, four-stroke, three-cylinder engine.

**6 Rear suspension**
Two shock absorbers provide 34.3cm (13.5in) of rear suspension for a smoother ride.

**7 Heated grips**
Deluxe snowmobiles include amenities like heated handgrips, thumb warmers and an adjustable heated seat to mitigate sub-zero temperatures.

## Snow vehicles by the numbers

### Snowmobile

**Speed:** 75km/h (47mph)
**Capacity:** 1-2 people
**Cost:** £4,900-£9,200 ($8,000-$15,000)

### Icebreaker

**Speed:** 1.5 knots (2.8km/h; 1.7mph)
**Capacity:** 140 people
**Cost:** £610mn ($1bn)

### Dog sled

**Speed:** 40km/h (25mph)
**Capacity:** 1 musher; 12 dogs
**Cost:** £180-£600 ($300-$1,000) for sled; £9,200 ($15,000) to lease dogs for a year

### Downhill skis

**Speed:** 64km/h (40mph)
**Capacity:** 1 person
**Cost:** £180-£600 ($300-$1,000)

> "Snowmobiles combine the traction of a Sno-Cat with the speed and manoeuvrability of a skier"

specific type of traction. For grooming deep snow, long and straight steel tracks offer the best grip. To avoid slippage on steep side hills, rubber-biting edges are arranged in a zigzag pattern to provide traction in multiple directions at once. But for maximum speed and control on ice, nothing beats sharp metal studs that can cut into the frozen surface.

In contrast, one of the fastest ways to travel across snow-packed terrain is to abandon traction altogether. Skis and snowboards are designed to minimise friction, using slick polyethylene plastic and fresh applications of wax across the base of the board while still maintaining control with sharpened edges.

To lend them strength and stiffness, skis and snowboards are built around a hardwood core sandwiched between layers of fibreglass. The individual glass strands in the fibreglass are angled at 45 degrees, 0 degrees and -45 degrees to increase torsional stiffness – a measure of how much a material can twist.

Hovercrafts take frictionless snow travel to a whole new level, using large fans to force air underneath the vehicle's platform where it's contained by a flexible skirt. The pressure created by the trapped, circulating airflow is enough to lift the platform off the difficult terrain altogether, allowing the vessel to cruise friction-free over the deepest drifts of soft snow or thinnest lake ice. Hovercrafts sacrifice braking and handling for free-floating power, so if you're going to try hovering on snow, stick to large open fields or frozen lakes and leave the forested mountain trails to snowmobiles.

Snowmobiles combine the traction of a Sno-Cat with the speed and manoeuvrability of a skier. A single-studded track in the back provides forward thrust while a pair of swivelling skis up front provide low-friction steering. The tracks are custom-engineered in a wide variety of configurations to handle diverse snow conditions and riding styles.

For instance, trail riders look for tracks with steel studs for ice and medium-height teeth (called lugs) that rip into hard-packed snow. Cross-country and mountain riders, who need maximum traction and control in deep powder, want tracks with extra-tall lugs – ie five to 7.6 centimetres (two to three inches). Snowmobile racers compete on compacted snow, so racing lugs are made from extra-hard compounds that increase bite strength for greater thrust. There are even super-smooth, lugless street-racing snowmobile tracks for asphalt drag races.

Many ski resorts and national parks now court snow-loving tourists with snow coach tours. A snow coach is a heavily modified mashup of a snowmobile and a 30-passenger van. Like a snowmobile, the snow coach has a pair of massive tracks in the back and either two oversized skis or two additional tracks in the front. The tracks are powered by replacing the two back wheels of the coach with heavy-toothed gears. As torque is applied, the track is driven forward, powering the vehicle through deep powder for unspoiled, off-the-track views of remote peaks and winter wildlife.

Lighter trucks are getting in on the winter mod craze too. If winter tyres don't offer enough deep-tread traction, you can buy a set of four wheel-mounted tracks that can be attached and removed in 15 minutes. This innovative system doesn't require heavy modifications. In fact, the wheels power the tracks. Each wheel on a

## The power of icebreakers

Icebreakers – those massive vessels that cut paths through frozen seas – should really be called ice smashers. An icebreaker's bow is wide and round like the bottom of a bathtub. Icebreakers don't slice through sea ice with a razor-sharp nose, as you might expect. They use that smooth, rounded bow to glide on top of the ice and crush it into pieces with the ship's tremendous weight. To smash through a particularly thick section of ice, the captain will back up and bring the vessel to full ramming speed.

The world's biggest icebreakers run on nuclear power to provide constant thrust without need for refuelling in remote locations. Dual-functioning ships have a conventional sharp bow to navigate on the high seas, but when operating in reverse, the ship's propeller agitates the water beneath the ice while the rounded rear of the hull slides over and smashes through the ice sheet. Even icebreakers can get snared by thick ice floes though, as demonstrated by the Chinese icebreaker Xue Long, which got trapped near Antarctica in 2013.

Icebreakers carve paths through ice for other ships


AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK
Watch a hi-tech snowblower in action now!
www.howitworksdaily.com


DID YOU KNOW? During the 1,600km (1,000mi) Iditarod race, sled dogs need to consume 10,000 calories a day!

standard 4x4 pickup truck runs atop what looks like a small treadmill. The wheels snap into place between four tight-fitting rollers and can drive the tracks both forward and backward. Flexible ski tips on the front and back of each track help them climb tall snowdrifts and navigate down steep slopes.

More than 50 years after Fuchs and Hillary traversed the Antarctic in a squadron of Sno-Cats, the British Antarctic Survey (BAS) continues to study the past and present of the polar ice sheets for clues to our planet's climatic future.

The BAS relies on tracked trucks, cranes and tractor-mounted snowblowers to tame the extreme terrain. A two-person snowmobile proposed by BAS (known as Ninety Degrees South) features two wide, near-spherical wheels up front instead of skis, for stability. There are six knobbly treads along the rims for traction and the rear tracks are mounted on a large, Z-shaped, spring-loaded shock absorber. Perhaps its coolest innovation yet is a unit that travels 30 metres (98 feet) ahead of the snowmobile on a cord, using ground-penetrating radar to scan the ice for dangerous hidden crevasses.

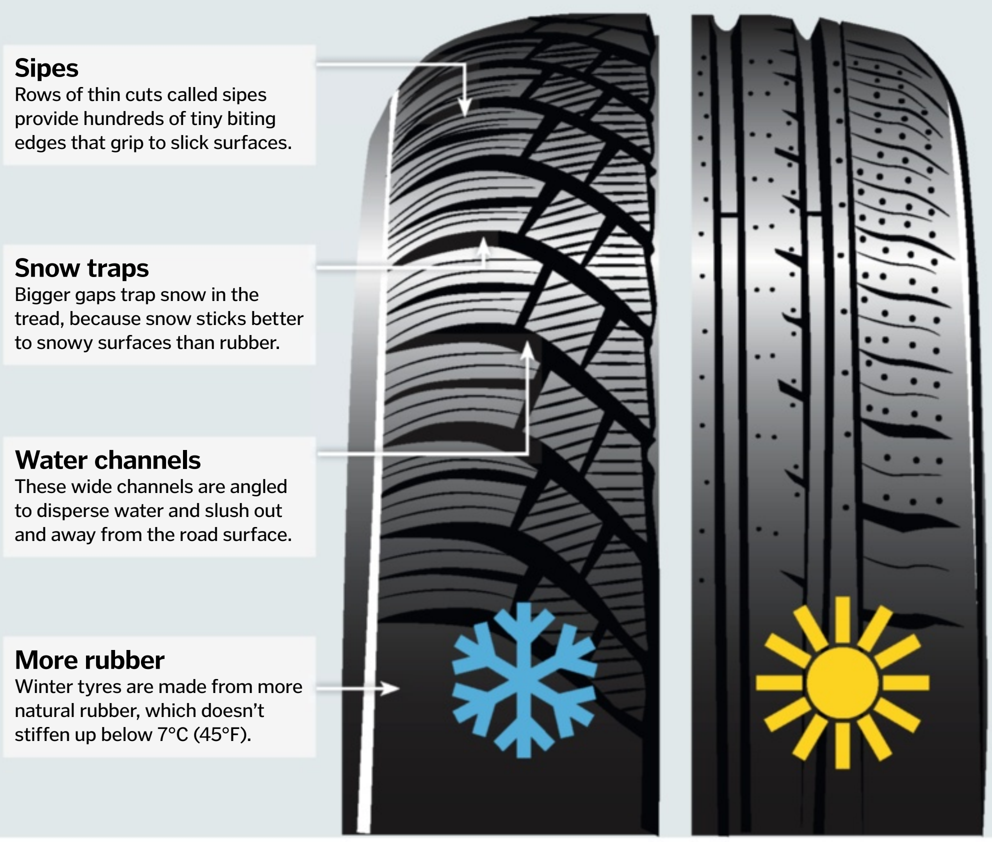
## Snow travel without an engine

Starting 10,000 years ago, humans relied on snowshoes and skis to migrate and hunt across vast stretches of frozen wilderness. The physics of snowshoes is simple – a larger surface area distributes the weight, preventing you from breaking the surface and sinking.

Skis employ the same physics, but also add the dimension of speed. Skis are polished and waxed to decrease friction and edges are sharpened for more efficient turns. Dog sleds combine the speed of skis with the genetic superiority of sled dogs and their relentless urge to run. In the case of dogs like Siberian huskies, fur comes in layers in order to trap heat, so they can withstand temperatures as low as -60 degrees Celsius (-76 degrees Fahrenheit). Hair between the dogs' toe pads provides extra traction on slippery surfaces.

## Winter tyres vs summer tyres

**What are the key differences between these seasonal tyres?**




## Winter mods

In parts of the world, driving through deep snow and over treacherous ice is a part of everyday life. The first line of attack is winter tyres. These are made from more natural rubber than all-season tyres which remains soft at lower temperatures than synthetics. The channels between the tread are deeper and wider to displace water and trap snow; as it turns out, snow sticks better to a snow-covered road than rubber. Tiny cuts (sipes) provide improved traction on ice by increasing the number of biting edges. Snow chains, wrapped tightly around the tyre, cut deeply into snow and ice to provide serious traction, but must be removed on cleared roads as to not damage the surface. An innovation for emergency vehicles is OnSpot, a push-button chain system that spins a wheel of chains between the tyre and the snow. Then there are new track systems that convert pickup trucks into snowmobiles. Mattracks (pictured) replace tyres with four track units powered by the front and rear axles, while the Track N Go system is more like two pairs of tracked shoes that can be fitted and removed in minutes and the tyres are what rotate the tracks.

© Yamaha; Thinkstock; Alamy; Corbis

> "Cruise control enables the vehicle to maintain a consistent speed without having to press the accelerator"

# How does cruise control work?

Take your foot off the gas and let your car set the pace…

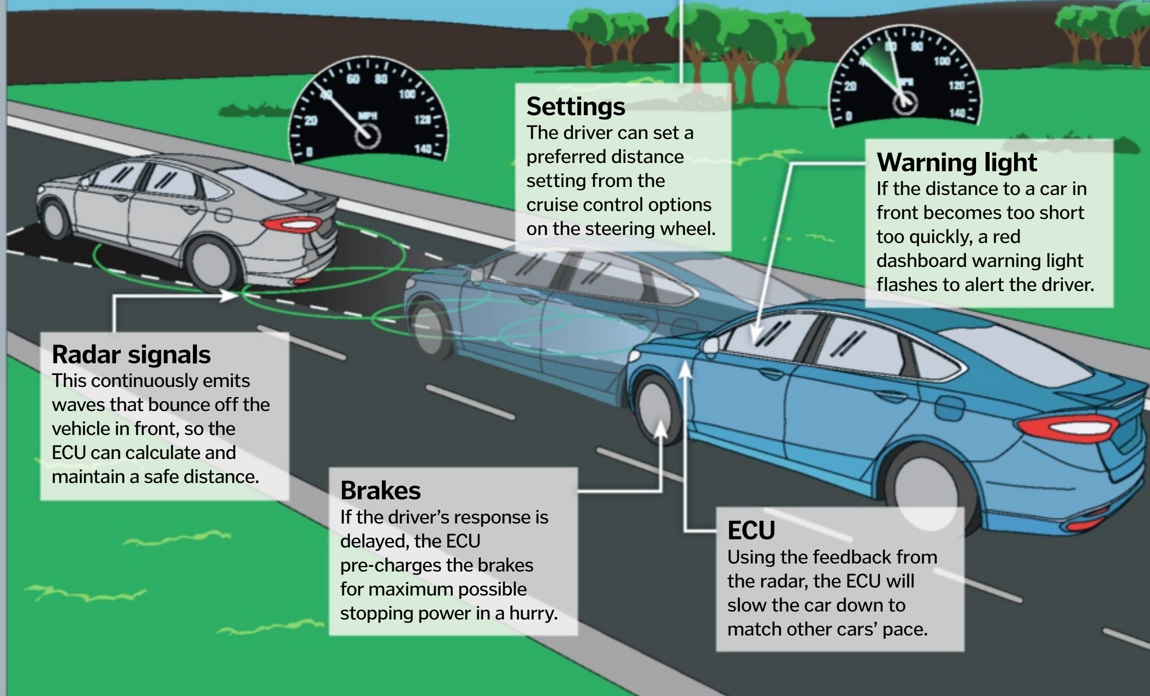
Cruise control is an electrical function that allows a vehicle to travel automatically at a speed preset by the driver. It is managed by a car's engine control unit (ECU). The driver only needs to touch the brakes to take full control again. A modern evolution of this tech is adaptive cruise control, which uses radar in the front of the vehicle to emit signals that bounce off anything in front, constantly measuring the distance to the leading vehicle.

If the radar detects that a preset distance has been reached, the ECU adjusts the car's speed to match the leading car, maintaining a safe gap.

Cruise control enables the vehicle to maintain a consistent speed without the driver having to press the accelerator pedal. Keeping a consistent speed enhances MPG, saving on fuel and making the car more economical.


## Adaptive cruise control

**Today's cars are smart enough to modify their own speed**



**Settings**
The driver can set a preferred distance setting from the cruise control options on the steering wheel.

**Warning light**
If the distance to a car in front becomes too short too quickly, a red dashboard warning light flashes to alert the driver.

**Radar signals**
This continuously emits waves that bounce off the vehicle in front, so the ECU can calculate and maintain a safe distance.

**Brakes**
If the driver's response is delayed, the ECU pre-charges the brakes for maximum possible stopping power in a hurry.

**ECU**
Using the feedback from the radar, the ECU will slow the car down to match other cars' pace.

# Auto-dimming mirror science

Learn how these smart mirrors help to keep headlight glare at bay

Auto-dimming mirrors help prevent glare from the headlights of other cars, so drivers can't be dazed.

The science behind auto-dimming mirrors lies in electrochromics, which uses electricity to darken the mirror's surface. This process works by a low-voltage current passing through a layer of gel that sits between two glass plates. As this gel conducts electricity, the current spreads evenly across the mirror's surface and the gel changes colour due to either gaining or losing electrons (ie a redox reaction).

Another crucial part of the auto-dimming mirror system is a sensor that monitors the amount of glare in relation to a forward-facing sensor, which determines ambient light. When the level of glare becomes too great, the microprocessor is programmed to release electricity. The brighter the glare, the more the mirror will darken, and when the glare itself reduces, the current is stopped, clearing the mirror again.

## Electrochromics in action

**The main components of an anti-glare mirror in focus**

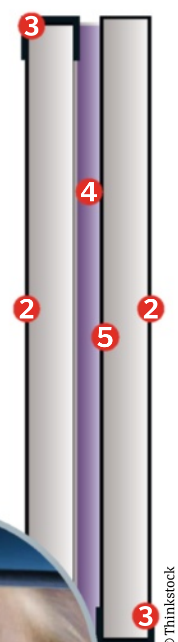
**1 Glare sensor**
This backward-facing sensor measures the intensity of light from vehicle headlights behind.

**2 Glass**
These two small panes sandwich the conductible gel, ensuring the driver cannot touch it.

**3 Electrodes**
These feed the low-voltage electricity between each other via the central gel.

**4 Electrochromic gel**
Allows electricity to pass between the electrodes, completing the circuit and darkening the mirrors.

**5 Reflective material**
This surface simply reflects light, so the driver can still see what is behind.





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"The enormous weight borne by a full transporter is distributed over many axles with heavy-duty suspension"

# Car transporter engineering

Find out what technology enables these monster trucks to haul many cars over great distances

Loading a car transporter is a spatial reasoning puzzle. The vehicle, consisting of a front tractor cab and a rear semi-trailer, has two decks, each composed of several tilting platforms. They can be loaded in a number of ways in order to maximise the available space.

The upper deck is often over two metres (6.6 feet) off the ground, but when the transporter is empty, the rear end can be lowered to act as a ramp. The first car is driven on to the transporter, and once it is in position it is secured with heavy-duty ties. Many cars are manufactured with holes in the chassis, designed specifically for this purpose. Using these holes, the cars are firmly attached to the transporter with chains or straps. Chocks and bollards may also be used to prevent the cars from rolling, and if the car lacks attachment points, the wheels themselves can be strapped down to make sure it stays still during transit.

Each car sits on a hydraulic platform, and once it has been secured, the platform is tilted to create more space, allowing the cars to be overlapped nose-to-end as they are stacked. The platforms can be arranged in a variety of configurations and cars can be driven on to face both forwards or backwards.

The enormous weight borne by a full transporter is distributed over many axles with heavy-duty suspension. A tractor with a diesel engine has the pulling power to move the loaded trailer. Large car transporters can carry loads exceeding 30,000 kilograms (66,000 pounds), but unconventional designs can take even more cars. For instance, extremely wide transporters in China can carry not one but two rows of six cars, side by side on the top deck.


Workers load a car onto a flatbed transporter using a winch

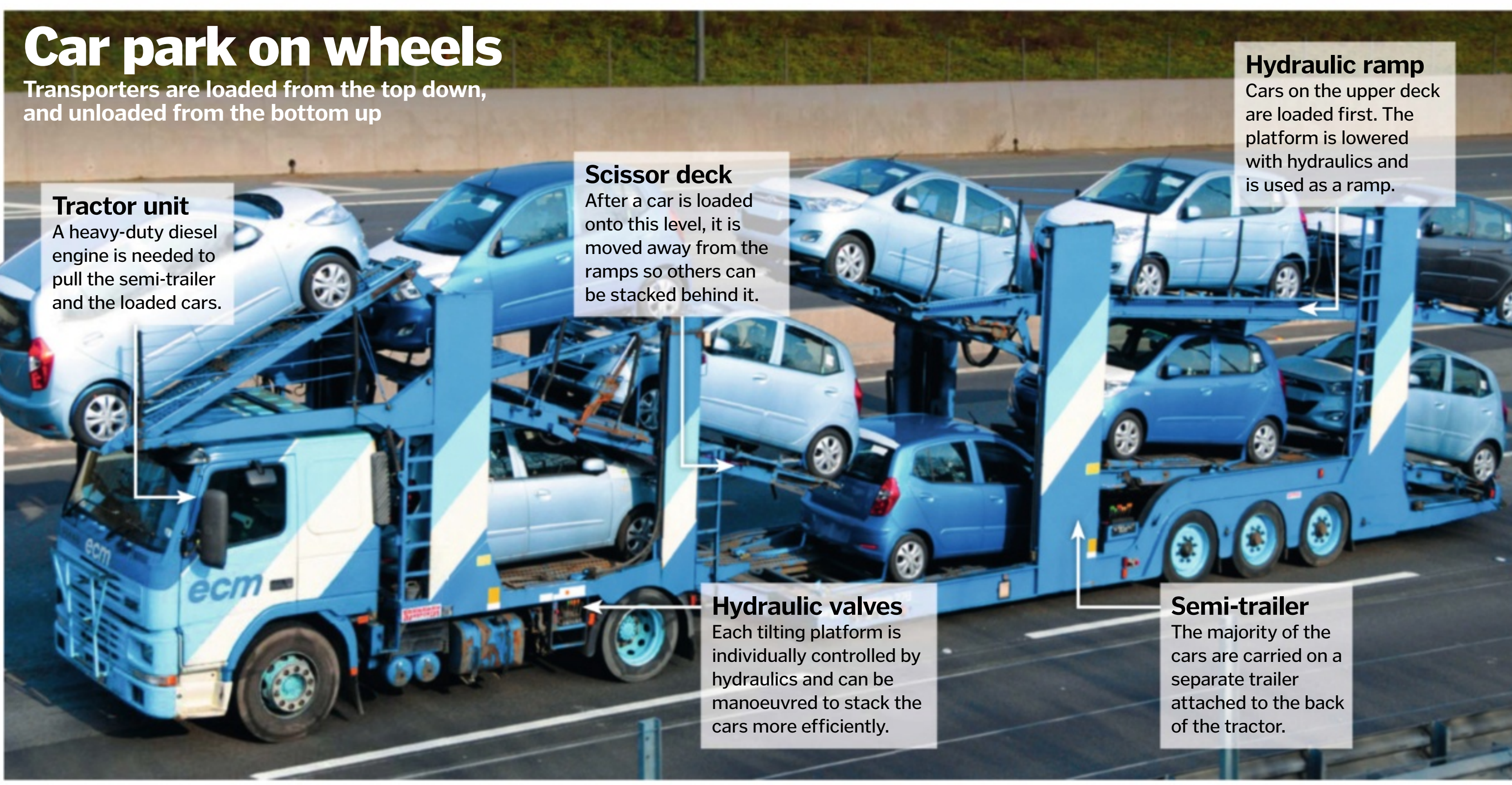
## Tow truck tech

Tow trucks are essentially car transporters for one and come in a number of formats. Wheel-lift trucks use a cradle to lift the driving wheels away from the floor, touching only the tyres. These can be manually fitted, or deployed automatically using hydraulics operated from the cab of the tow truck. Once the cradles are fastened and in place, the tow boom is lifted, pulling the driving wheels away from the ground so the vehicle can be towed.

If a car is too damaged to be wheeled away, too heavy to be towed or four-wheel drive, flatbed transporters may be used instead. In this case, the car is lifted wholesale onto a flat trailer using a winch (as in the picture above).

## Car park on wheels

Transporters are loaded from the top down, and unloaded from the bottom up

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# FIRST VIEW

Take your first steps into exploring the wonders of the universe!

## STARTER **TELESCOPE**

3” mirror telescope with table mount, finder scope and two eyepieces.

d=76mm, f=300mm, included 12.5mm eyepieces (75x magnification) and 4mm eyepiece (24x), accepts standard 1.25” eyepieces. Very easy to set up and use.

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> "The water jet propulsion replaces the conventional propeller with a high-capacity pump"

# Next-gen lifeboats

## What makes the Shannon one of the most cutting-edge rescue boats in the world?

The latest vessel made by the Royal National Lifeboat Institution (RNLI) to enter service is the Shannon class – an innovative design incorporating a host of cutting-edge technology. Luke Blissett from the RNLI reveals: "The Shannon is the first RNLI lifeboat to be powered by water jets, making it the most agile lifeboat in the fleet." The Shannon is self-righting so even if it were to capsize in extreme conditions it could get itself out of trouble. This ability is achieved by having a watertight superstructure that makes the boat unstable when it is upside down.

"The Shannon's hull has been designed to minimise slamming of the boat in heavy seas," Blissett continues: "The crew sit in shock-absorbing seats making it safer and more comfortable for our volunteer crews." The hull is made from composites – a combination of glass and carbon fibres and epoxy resins for maximum strength while remaining lightweight. Once the moulding is completed with all the internal strengthening structures attached, the engines and equipment are installed. The deck and superstructure moulding are the last features to be fitted.

The water jet propulsion replaces the conventional propeller with a high-capacity pump that expels water from the rear for propulsion thrust and more manoeuvrability than previous lifeboats. "This increased manoeuvrability helps when precision matters, such as when operating alongside a stricken vessel," Blissett explains. The jets are less prone to damage and allow the lifeboat to operate in shallower waters. Capable of speeds of 25 knots (46 kilometres/29 miles per hour), the Shannon is 50 per cent faster than the models it replaces.

Beyond the boat's advanced structure, the RNLI has also made a full commitment to electronics on its next-gen lifeboats. The conventional steering wheel has disappeared, replaced by an electronic tiller arm placed in the armrest of the coxswain's seat. Facing them are displays that show all the required navigation, collision avoidance and monitoring information, and the remaining crew of five have similar displays.

"We will build at least 50 Shannon-class lifeboats over the next ten years," Blissett concludes. "Once the rollout is complete the RNLI will have achieved its aim of operating a lifeboat fleet around the coasts of the United Kingdom and Ireland consisting entirely of lifeboats capable of 25 knots and able to reach out to 100 miles [160 kilometres] offshore in all weathers."

## On board the Shannon

**Discover what features make the latest RNLI vessel one of the most advanced to ever patrol the seas**

### The statistics...

*RNLI Shannon*

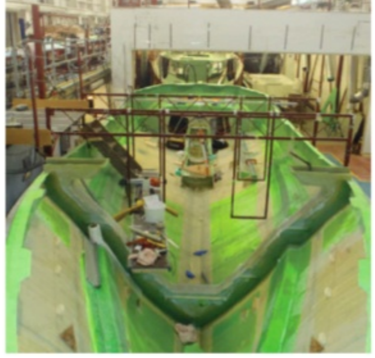
**Length:** 13.6m (45ft)
**Beam:** 4.5m (15ft)
**Draft:** 1m (3.3ft)
**Engine power:** 2x 650hp diesel
**Top speed:** 25 knots (46km/h; 29mph)
**Cost:** £1.5mn ($2.5mn)

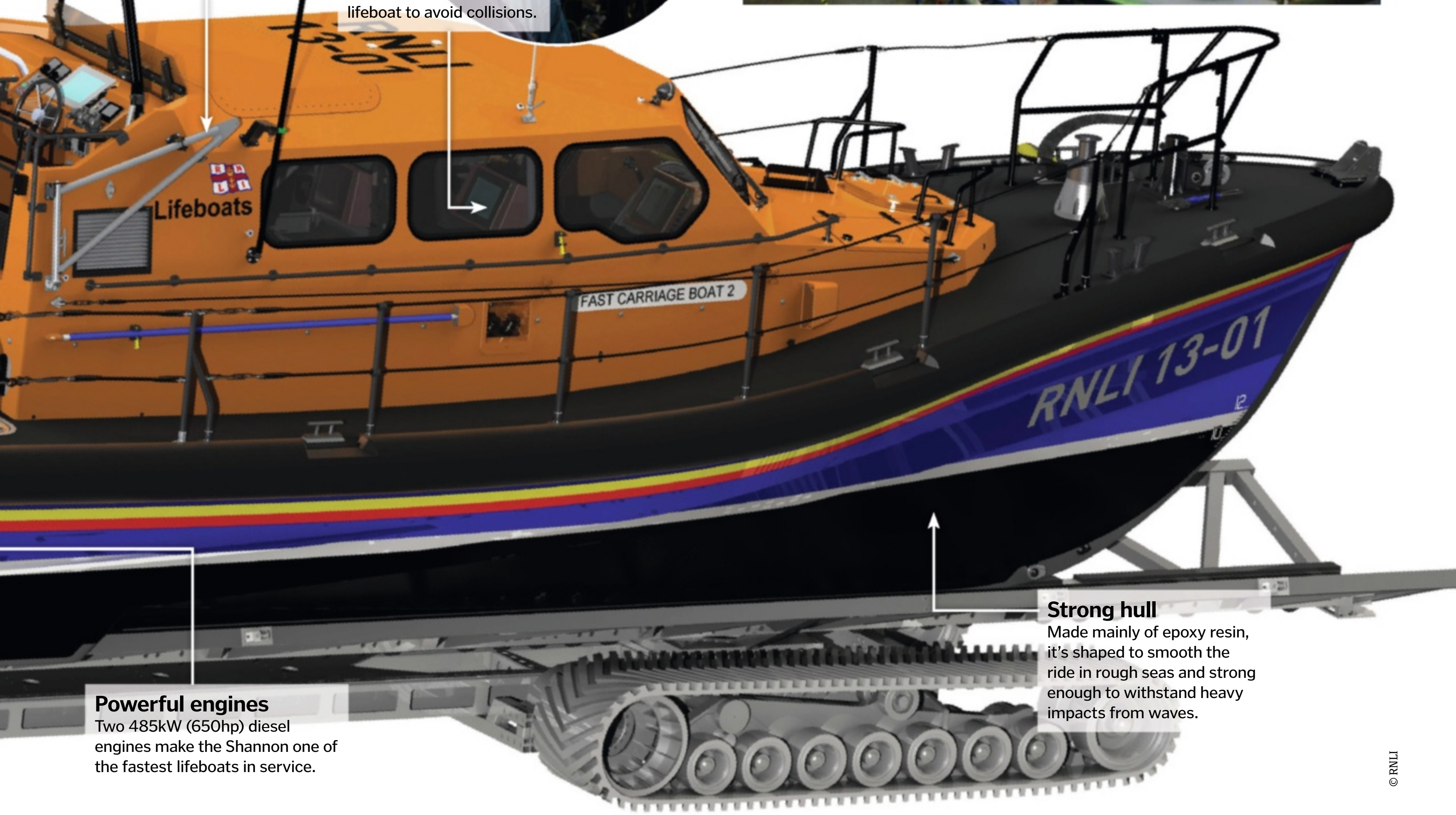
**DID YOU KNOW?** The Shannon can be launched from an open beach by a tractor and carriage that can negotiate steep gradients

## History of the RNLI

Since it was established in 1824 the lifeboats of the Royal National Lifeboat Institution have saved over 140,000 people from the sea. The aim was to give local seamen a safe boat to go to the rescue of those in peril. First they were rowing and sailing lifeboats that demanded supreme seamanship, before power lifeboats came. The constant evolution of lifeboat design has led to faster and more advanced vessels designed to tackle even the roughest waters in order to bring the crew and survivors safely back to shore.

These images show the process of building a Shannon lifeboat, from setting the hull to adding the cabin






**Recovery tools**
A small crane arm swings out to enable casualties to be lifted out of the water.

**Electronics**
Advanced displays in the cabin enable the crew to monitor and control the lifeboat to avoid collisions.

**Strong hull**
Made mainly of epoxy resin, it's shaped to smooth the ride in rough seas and strong enough to withstand heavy impacts from waves.

**Powerful engines**
Two 485kW (650hp) diesel engines make the Shannon one of the fastest lifeboats in service.

© RNLI

# Guide to the galaxy

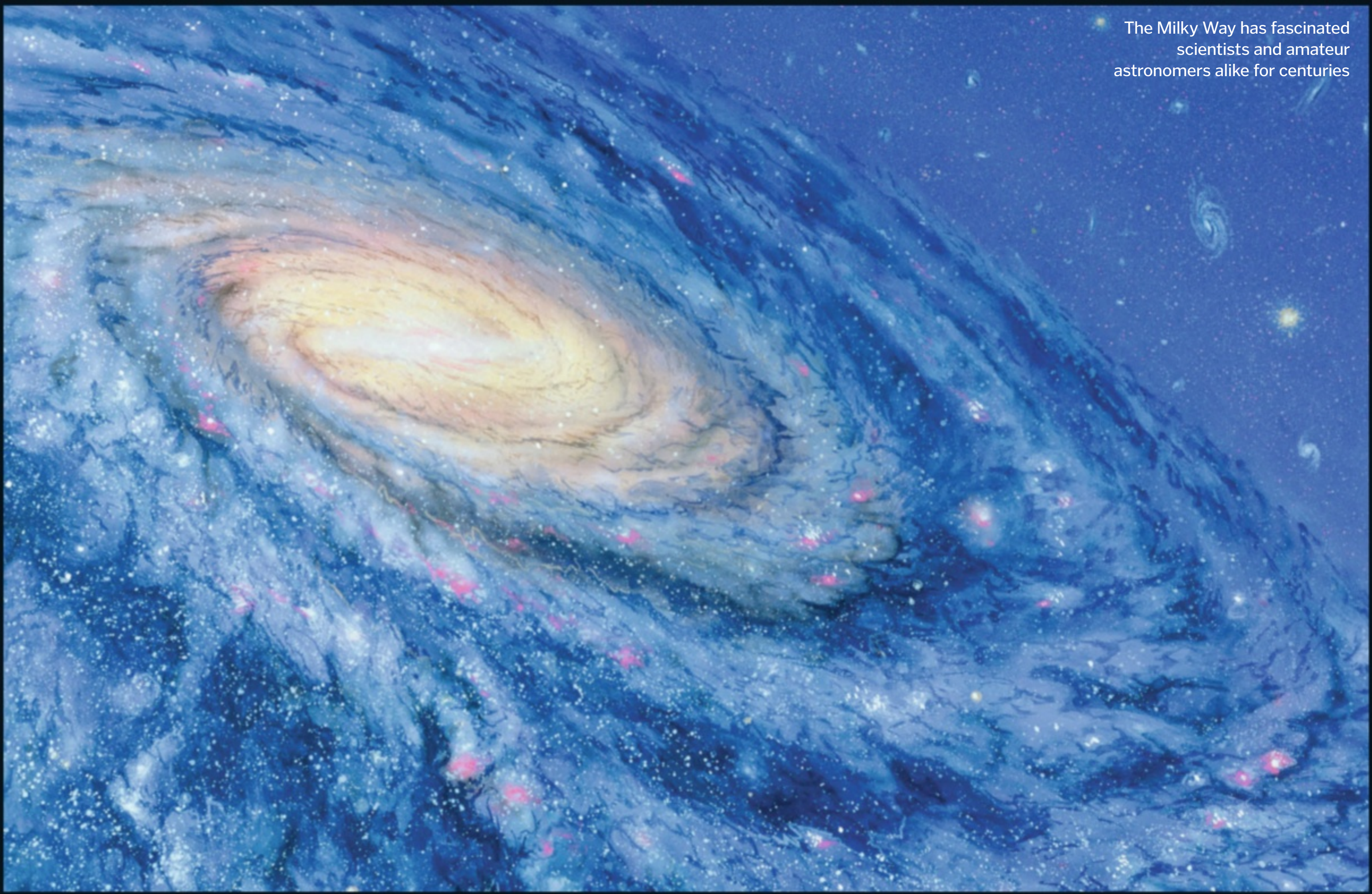
## Home to our Solar System and billions of other stars and planets we reveal the Milky Way's origins and where we fit in now…

Look up into the sky on a dark, clear night and every star you see is a part of our home galaxy – for the naked-eye observer, only a handful of tiny smudges of light mark objects in the wider universe. Dense, bright stars cluster along a faint river of light that ancient stargazers interpreted as a stream of milk spilt across the sky – the Milky Way that gives its name to our entire galaxy.

This distribution of stars gives us a good clue to its basic structure – viewed through binoculars, the Milky Way itself dissolves into clouds containing countless individual stars. Looking away from our galaxy, however, stars are relatively few and far between. This suggests that our Solar System is embedded in a more or less flat plane of stars – when we look across the plane, there are many stars stretching away over long distances in any given direction, while if we look 'above' or 'below', we see only the relatively nearby bodies of our galactic neighbourhood.

This was the basis for the first attempt to map our galaxy. In the 1770s and 1780s, German-born British astronomer William Herschel (discoverer of the planet Uranus) compiled detailed 'star counts' of different areas of the sky. Based on the faulty assumption that all stars had the same brightness, he eventually produced a chart that showed the Milky Way as a shapeless cloud with the Solar System at its centre.

Today, of course, our models are a lot more sophisticated. Herschel could hardly have dreamed that the Milky Way would eventually be mapped using radio waves, which were not even discovered until a century later. Since the Fifties, these waves have allowed astronomers to look beyond the star clusters and trace the distribution of huge clouds of hydrogen gas – a major component of the 'interstellar medium' that makes up the Milky Way's skeleton.



The Milky Way has fascinated scientists and amateur astronomers alike for centuries

# 5 TOP FACTS
## GALACTIC MINDS

**Galileo Galilei**
**1** Around 1610, renowned Italian polymath Galileo was the first person to look at the Milky Way through a telescope, reporting to the world that it was made up of countless individual stars.

**William Herschel**
**2** Herschel made the first map of the Milky Way in the 1780s by counting the stars in the field of his telescope in 600 directions – a method he called 'star gauging'.

**Jacobus Kapteyn**
**3** In 1904, Dutch astronomer Kapteyn discovered evidence the galaxy is rotating. He led a huge effort to map the Milky Way based on improved astronomical knowledge.

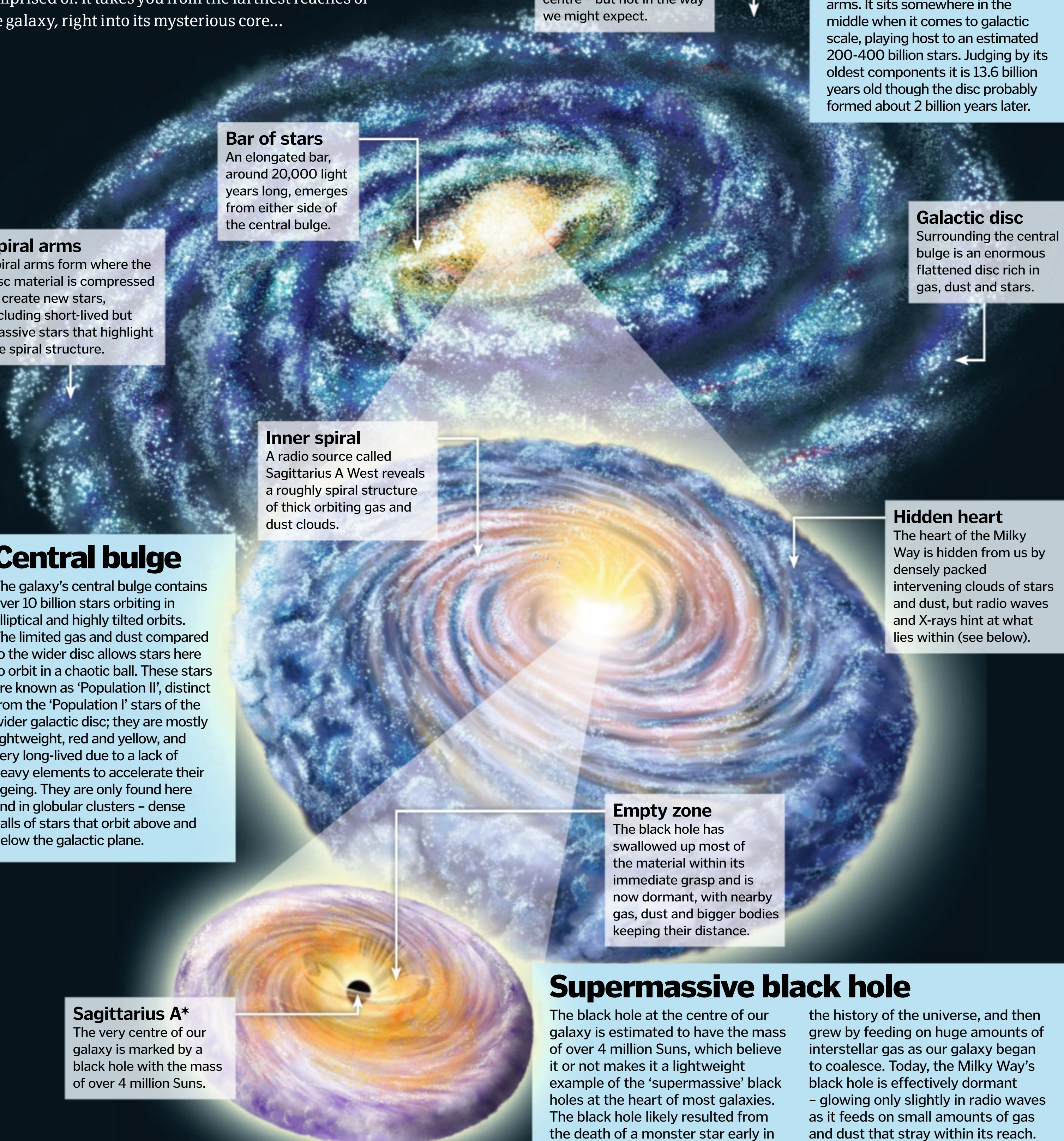
**Jan Oort**
**4** In the Fifties, Jan Oort built one of the first large radio telescopes and used it to map the distribution of interstellar hydrogen, confirming the Milky Way's spiral structure.

**Hipparcos**
**5** From 1989 to 1993, this European Space Agency satellite collected data for over 2 million stars, compiling the first accurate atlas of our galactic neighbourhood.

**DID YOU KNOW?** *The word 'galaxy' comes from the Ancient Greek name for the Milky Way: galaxias kyklos*

# Anatomy of the Milky Way

To help you better understand the structure of our galaxy and its immense scale, here is an overview of the key components it is comprised of. It takes you from the farthest reaches of the galaxy, right into its mysterious core…



### Orbital speeds
Stars orbit at different speeds depending on their distance from the galactic centre – but not in the way we might expect.

## Spiral galaxy
The Milky Way is a disc-shaped galaxy some 120,000 light years in diameter, with four major spiral arms. It sits somewhere in the middle when it comes to galactic scale, playing host to an estimated 200-400 billion stars. Judging by its oldest components it is 13.6 billion years old though the disc probably formed about 2 billion years later.

### Bar of stars
An elongated bar, around 20,000 light years long, emerges from either side of the central bulge.

### Spiral arms
Spiral arms form where the disc material is compressed to create new stars, including short-lived but massive stars that highlight the spiral structure.

### Galactic disc
Surrounding the central bulge is an enormous flattened disc rich in gas, dust and stars.

### Inner spiral
A radio source called Sagittarius A West reveals a roughly spiral structure of thick orbiting gas and dust clouds.

### Hidden heart
The heart of the Milky Way is hidden from us by densely packed intervening clouds of stars and dust, but radio waves and X-rays hint at what lies within (see below).

## Central bulge
The galaxy's central bulge contains over 10 billion stars orbiting in elliptical and highly tilted orbits. The limited gas and dust compared to the wider disc allows stars here to orbit in a chaotic ball. These stars are known as 'Population II', distinct from the 'Population I' stars of the wider galactic disc; they are mostly lightweight, red and yellow, and very long-lived due to a lack of heavy elements to accelerate their ageing. They are only found here and in globular clusters – dense balls of stars that orbit above and below the galactic plane.

### Empty zone
The black hole has swallowed up most of the material within its immediate grasp and is now dormant, with nearby gas, dust and bigger bodies keeping their distance.

### Sagittarius A*
The very centre of our galaxy is marked by a black hole with the mass of over 4 million Suns.

## Supermassive black hole
The black hole at the centre of our galaxy is estimated to have the mass of over 4 million Suns, which believe it or not makes it a lightweight example of the 'supermassive' black holes at the heart of most galaxies. The black hole likely resulted from the death of a monster star early in the history of the universe, and then grew by feeding on huge amounts of interstellar gas as our galaxy began to coalesce. Today, the Milky Way's black hole is effectively dormant – glowing only slightly in radio waves as it feeds on small amounts of gas and dust that stray within its reach.

*"Surrounding the central bulge is a flattened disc of stars, about 1,000 light years deep"*

The biggest scientific breakthrough came with the discovery of galaxies *beyond* the Milky Way, back in the Twenties. Astronomers could now compare the Milky Way to other galaxies and it soon became clear that its properties were similar to those of so-called 'spiral nebulas', like the nearby Andromeda galaxy.

As a result, we now know that the Milky Way is a vast stellar pinwheel slowly spinning around a huge central bulge of old red and yellow stars. The visible part of the spiral is more than 100,000 light years across, with invisible material stretching out much farther. Our own Solar System is not at the centre, as Herschel thought, but halfway across the disc – 26,000 light years from the Milky Way's crowded core. And what's more, our Sun is just one fairly average, unremarkable star among 200 to 400 billion others.

Comparisons with other galaxies also suggest the Milky Way is a 'barred' spiral – its arms emerge from the ends of a dense bar of stars that stretches out on either side of the central bulge. The bulge is roughly spherical and about 16,000 light years across, while the bar is at least 20,000 light years long.

Surrounding the central bulge is a flattened disc of stars, about 1,000 light years deep, with the spiral arms running across it. In distant galaxies the arms are the only visible part of the disc, but the fainter background of more subdued stars and interstellar material must still be there, since it is this that ultimately gives rise to the spiral.

Despite appearances, the spiral arms cannot be solid structures – if they were, they would rapidly wind themselves up around the core, and we know from countless other galaxies that this simply doesn't happen.

Instead, it seems that the spiral arms are long-lived but constantly regenerating features – in a sense stellar 'traffic jams' where material in the disc clumps together. This not only concentrates the light of older 'disc stars' moving in and out of the spiral zone, but more importantly triggers new waves of star formation that give rise to future generations of brilliant but short-lived heavyweight stars.

These hot blue-white stars, clustered together as they emerge from starbirth nebulas, shine with the brightness of many thousands of Suns, but live and die in just a few million years – before their long orbits around the galaxy can carry them out of the spiral arm region. Only less massive and more sedate stars (like our Sun) live for long enough to emerge into the disc between the spiral arms.

But what actually causes the 'traffic jam' (known to astronomers as a density wave) in the first place? It appears to be a pattern that naturally arises when the slightly elliptical (stretched) orbits of disc stars and interstellar material are pulled in a particular direction by the gravity of another nearby galaxy. Because any orbiting object moves slowest on the outer part of its orbit, this kind of tugging eventually means that everything is slowing down in the same place, giving rise to the spiral traffic jam.

## The Milky Way in numbers

**200-400bn**
Number of stars in the galaxy

**240mn**
Orbital period of Sun around centre in years

**100bn**
Estimated number of Earth-like planets

**120,000**
Diameter in light years

**13.6bn**
Age of Milky Way's oldest stars in years

**220km/s**
Speed of Sun's orbit around the centre

**600km/s**
Speed of Milky Way through space

## When galaxies collide…

Also known as Messier 31, the Andromeda galaxy is our nearest large galactic neighbour – a spiral even larger than our own, just 2.5 million light years away. Although Andromeda's diameter is larger than our own galaxy's at about 140,000 light years, and it contains more than double the number of stars at about a trillion, it still weighs less than the Milky Way, which seems to contain more invisible dark matter.

The Milky Way and Andromeda are the largest members of the Local Group, a small galactic cluster that contains several dozen smaller galaxies. These two galactic heavyweights are also attracted to one another by gravity, and are moving towards each other at about 300 kilometres (186 miles) per second. This will cause them to collide in around 4 billion years from now – perhaps eventually merging together to become a single supergiant elliptical galaxy.

# 5mn Suns

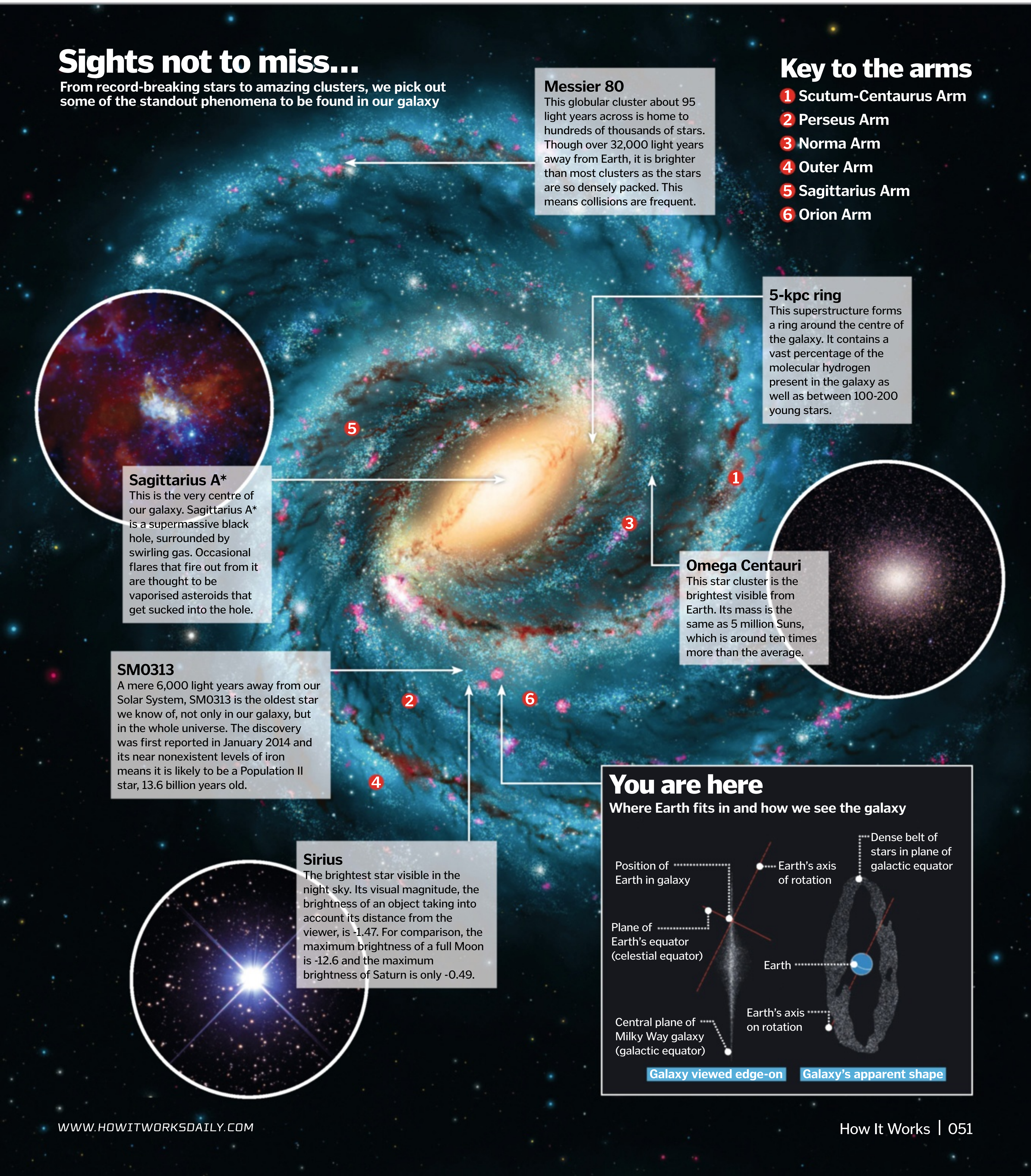
## BRIGHTEST STAR IN THE MILKY WAY

The most luminous star in our galaxy is 7,500 light years away. Eta Carinae has a mass equal to about 100 Suns, but a luminosity 5 million times greater than the Sun. It is set to go supernova at any point.

**DID YOU KNOW?** *In Earth's skies, the Milky Way is at its brightest towards the constellation of Sagittarius*

# Sights not to miss...

**From record-breaking stars to amazing clusters, we pick out some of the standout phenomena to be found in our galaxy**




## Key to the arms

1. Scutum-Centaurus Arm
2. Perseus Arm
3. Norma Arm
4. Outer Arm
5. Sagittarius Arm
6. Orion Arm

### Messier 80

This globular cluster about 95 light years across is home to hundreds of thousands of stars. Though over 32,000 light years away from Earth, it is brighter than most clusters as the stars are so densely packed. This means collisions are frequent.

### 5-kpc ring

This superstructure forms a ring around the centre of the galaxy. It contains a vast percentage of the molecular hydrogen present in the galaxy as well as between 100-200 young stars.

### Sagittarius A*

This is the very centre of our galaxy. Sagittarius A* is a supermassive black hole, surrounded by swirling gas. Occasional flares that fire out from it are thought to be vaporised asteroids that get sucked into the hole.

### Omega Centauri

This star cluster is the brightest visible from Earth. Its mass is the same as 5 million Suns, which is around ten times more than the average.

### SM0313

A mere 6,000 light years away from our Solar System, SM0313 is the oldest star we know of, not only in our galaxy, but in the whole universe. The discovery was first reported in January 2014 and its near nonexistent levels of iron means it is likely to be a Population II star, 13.6 billion years old.

### Sirius

The brightest star visible in the night sky. Its visual magnitude, the brightness of an object taking into account its distance from the viewer, is -1.47. For comparison, the maximum brightness of a full Moon is -12.6 and the maximum brightness of Saturn is only -0.49.

## You are here

**Where Earth fits in and how we see the galaxy**

> "Our Milky Way is surrounded by more than a dozen smaller satellites under its gravitational pull"

And there are plenty of nearby galaxies to do the hard work – our Milky Way is surrounded by more than a dozen smaller satellites under its gravitational pull. The most famous of these are the Magellanic Clouds, two irregular clouds of gas and stars that lie 160,000 and 200,000 light years from Earth and look like isolated chunks of the Milky Way in southern skies. Just as influential are the much smaller Sagittarius Dwarf Elliptical and Canis Major Dwarf galaxies, both of which are currently colliding with, and ultimately being absorbed by, our own spiral.

Everything in the Milky Way is in constant motion. Stars in the central bulge travel in tilted and stretched orbits around the huge concentration of mass in the core, while farther out, stars in the disc tend to follow flatter, more circular orbits. An important reason for this difference is that the disc is a mix of stars, gas and dust; stars on their own can follow more chaotic orbits with little risk of collision with their neighbours, but clouds of gas and dust collide all the time. This tends to force them into uniform motion, and since the disc stars originate from within the gas and dust clouds, they tend to inherit their movement.

While the speed of orbiting stars changes with distance from the centre, it doesn't do so in quite the way we'd expect, presenting another puzzle. Stars across most of the disc move at more or less the same speed, rather than moving much more slowly at greater distances from the core. This suggests that the distribution of mass in our galaxy doesn't match the distribution of its visible matter, and that there's a huge amount of invisible material beyond the confines of the visible Milky Way. Astronomers call this mysterious substance 'dark matter', and there's good evidence that it outweighs visible matter in our galaxy by a factor of ten to one.

Looking in the opposite direction, toward the galactic centre, stellar orbits also help us probe the core of our galaxy. Here, stars seem to move constantly faster and faster, suggesting an immense concentration of mass at the very centre of our galaxy, coinciding with a source of radio waves and X-rays known as Sagittarius A*. This is now known to be an enormous black hole with the mass of over 4 million Suns compressed in a region far smaller than the Solar System – the dark secret at the heart of our fascinating galaxy.

## Gaia: mapping the Milky Way

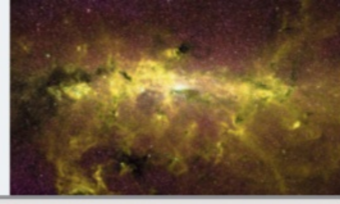
In December 2013, the European Space Agency launched a satellite that aims to revolutionise our view of the Milky Way. Gaia is a space telescope designed to survey more than a billion stars, compiling the most detailed map of our galaxy to date. It reached its operational orbit, some 150 million kilometres (93.2 million miles) from Earth, in January 2014.

Gaia uses a geometric technique known as the parallax method. If a star is close enough to our Solar System, then its apparent position in the sky will change very slightly when viewed from opposite sides of Earth's orbit (the same effect makes your outstretched finger appear to shift against more distant objects when you view it through one eye and then the other). By measuring this 'parallax shift' it's possible to calculate the star's distance using simple geometry. For all but the closest stars, the angles involved are absolutely tiny, but Gaia will still be able to measure objects up to 30,000 light years away to a precision of 20 per cent.

**STRANGE BUT TRUE**
**ODDBALL SHAPE**

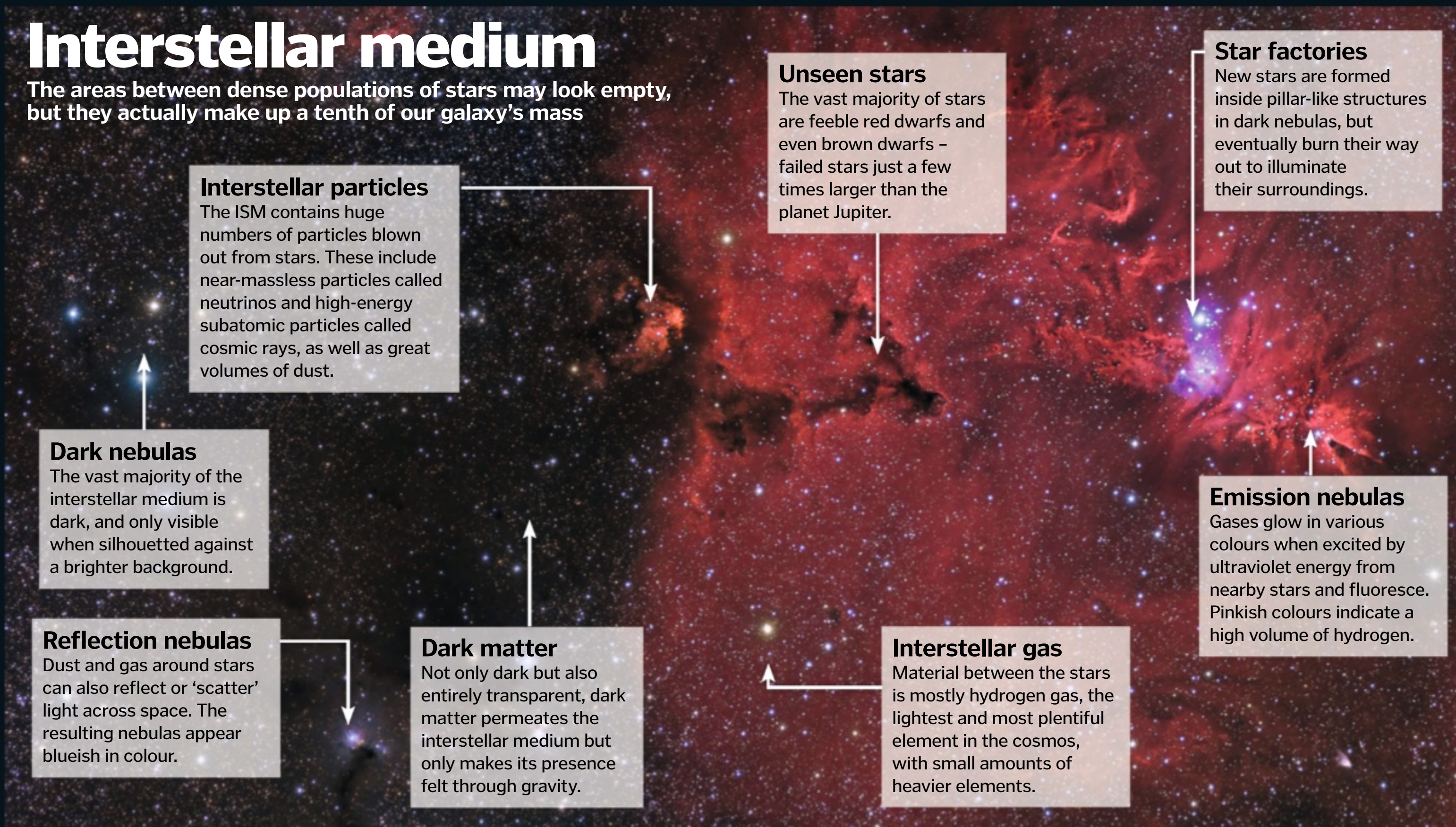
## What shape is the Milky Way's central bulge?

**A** Oval **B** Pretzel-shaped **C** Peanut-shaped



**Answer:**
According to a recent infrared survey of the galactic bulge, the stars have an uneven distribution that makes it resemble a peanut from some angles. We can't be certain why the stars are bunched together in this unusual way.

**DID YOU KNOW?** *The Milky Way's disc is slightly warped by the pull of the nearby Magellanic Clouds*



# Interstellar medium

**The areas between dense populations of stars may look empty, but they actually make up a tenth of our galaxy's mass**

### Interstellar particles
The ISM contains huge numbers of particles blown out from stars. These include near-massless particles called neutrinos and high-energy subatomic particles called cosmic rays, as well as great volumes of dust.

### Unseen stars
The vast majority of stars are feeble red dwarfs and even brown dwarfs – failed stars just a few times larger than the planet Jupiter.

### Star factories
New stars are formed inside pillar-like structures in dark nebulas, but eventually burn their way out to illuminate their surroundings.

### Dark nebulas
The vast majority of the interstellar medium is dark, and only visible when silhouetted against a brighter background.

### Emission nebulas
Gases glow in various colours when excited by ultraviolet energy from nearby stars and fluoresce. Pinkish colours indicate a high volume of hydrogen.

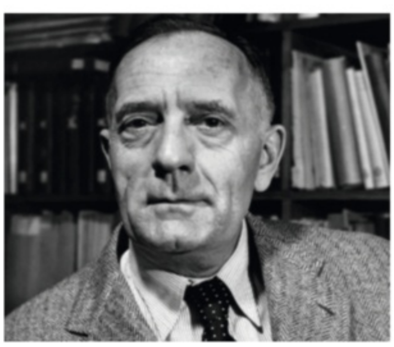
### Reflection nebulas
Dust and gas around stars can also reflect or 'scatter' light across space. The resulting nebulas appear blueish in colour.

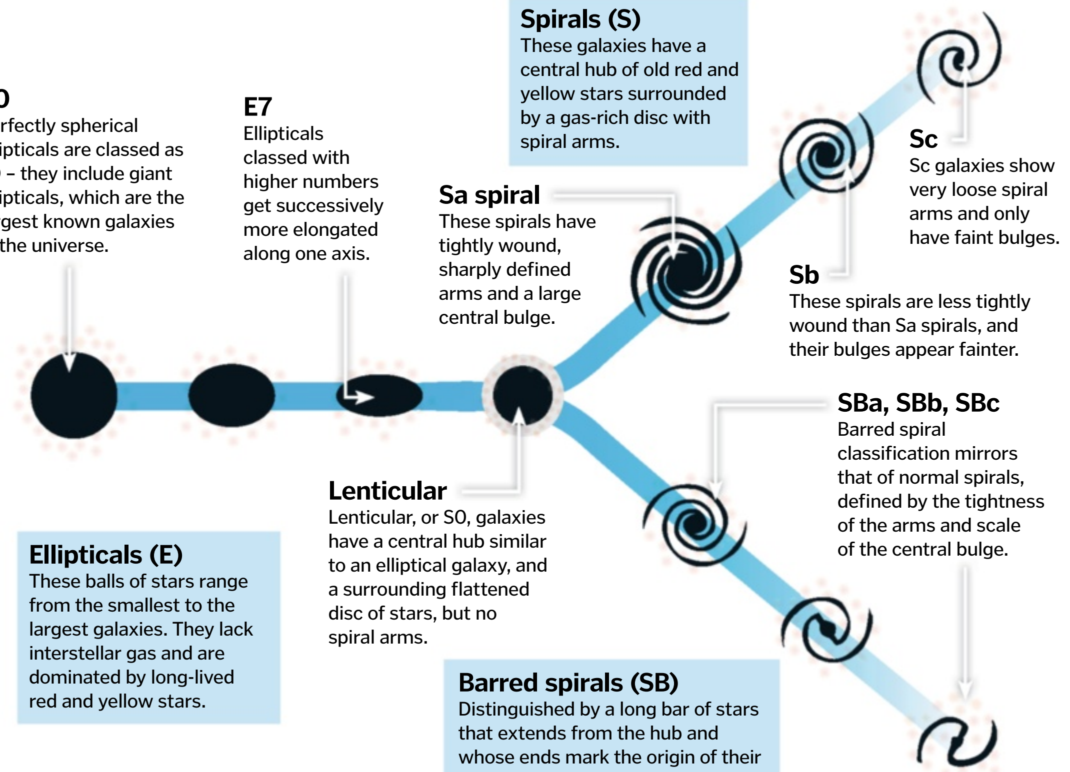
### Dark matter
Not only dark but also entirely transparent, dark matter permeates the interstellar medium but only makes its presence felt through gravity.

### Interstellar gas
Material between the stars is mostly hydrogen gas, the lightest and most plentiful element in the cosmos, with small amounts of heavier elements.

# How does our galaxy shape up to others?

Edwin Hubble, the US astronomer who first proved the existence of galaxies beyond the Milky Way, soon recognised several different types and developed a classification system that has largely stood the test of time. Spirals were split into two broad groups – normal and barred – each further divided depending on the tightness and definition of their spiral arms. Elliptical or ball-shaped galaxies were classed by their shape, from the perfectly spherical to the highly elliptical. Hubble laid the galaxies out in what is known as a 'tuning fork' diagram, which he believed charted a pattern of galaxy evolution. We now know that the true life cycle of galaxies is even more complex than Hubble suspected.





### E0
Perfectly spherical ellipticals are classed as E0 – they include giant ellipticals, which are the largest known galaxies in the universe.

### E7
Ellipticals classed with higher numbers get successively more elongated along one axis.

### Spirals (S)
These galaxies have a central hub of old red and yellow stars surrounded by a gas-rich disc with spiral arms.

### Sa spiral
These spirals have tightly wound, sharply defined arms and a large central bulge.

### Sc
Sc galaxies show very loose spiral arms and only have faint bulges.

### Sb
These spirals are less tightly wound than Sa spirals, and their bulges appear fainter.

### SBa, SBb, SBc
Barred spiral classification mirrors that of normal spirals, defined by the tightness of the arms and scale of the central bulge.

### Lenticular
Lenticular, or S0, galaxies have a central hub similar to an elliptical galaxy, and a surrounding flattened disc of stars, but no spiral arms.

### Ellipticals (E)
These balls of stars range from the smallest to the largest galaxies. They lack interstellar gas and are dominated by long-lived red and yellow stars.

### Barred spirals (SB)
Distinguished by a long bar of stars that extends from the hub and whose ends mark the origin of their spiral arms. The Milky Way is thought to sit between SBb and SBc.

© NASA; ESA; SPL; Alamy; Getty

> "So far the probe has found evidence that Venus has recently been geologically active and might still be"

## Venus Express payload

**The instruments on this probe are a combination of new and old, with each tool controlled by its own team**

**1 MAG**
The magnetometer studies the interaction between the solar wind and the Venusian atmosphere.

**2 VIRTIS**
The ultraviolet/visible/near-infrared mapping spectrometer focuses on the lower atmosphere and tracks clouds.

**3 PFS**
The Planetary Fourier Spectrometer measures atmospheric and surface temperatures, as well as analysing the composition of the atmosphere.

**4 SPICAV/SOIR**
The Ultraviolet and Infrared Atmospheric Spectrometer searches for water and other compounds in the atmosphere.

**5 VMC**
The Venus Monitoring Camera images the entire surface in near-infrared, ultraviolet and visible wavelengths.

**6 VeRa**
The Venus Radio Science Experiment explorers Venus's ionosphere as well as several other properties of its atmosphere and surface.

**7 ASPERA**
The Analyser of Space Plasma and Energetic Atoms measures the outflow of particles from the atmosphere and the nearby solar wind. It also monitors their interaction.


# Exploring Venus

The Venus Express probe has been sending back fascinating data about our neighbouring planet since 2006…

The European Space Agency (ESA) acted quickly to modify the Mars Express mission to work for a trip to the second planet from the Sun, taking just three years from conception to launch. Taking off from the Baikonur Cosmodrome in Kazakhstan, Venus Express has been orbiting the planet for nearly eight years, coming closest to Venus at its north polar region and taking about 24 hours to complete one orbit.

Venus Express has undertaken the most detailed study of the planet to date. Its main focus is the Venusian atmosphere, studying its chemistry, dynamics, as well as interactions with both the solar wind and the surface.

ESA controls the probe from the Venus Express Mission Operations Centre based in Darmstadt, Germany. During orbit, an antenna at an ESA station close to Madrid, Spain, is used for communication. The spacecraft collects data while over Venus's north pole (when it is closest to the planet), stores the data, then transmits it when it's closer to Earth.

So far the probe has found evidence that Venus has recently been geologically active and might still be. Other highlights include the discovery of lightning in the atmosphere and the creation of meteorological maps so we now have a greater understanding of Venusian climate than ever before.

## Martian twin

The predecessor to the Venus Express, the Mars Express, launched in 2003, was the ESA's maiden mission to another planet. The craft is almost identical to the Venus Express. The mission has been extended multiple times and is currently scheduled through 2014. Mars Express has discovered pockets of water ice and evidence that indicates liquid water existed at some point in Mars's past. The mission also made close-up studies of the moon Phobos. Mars Express included a lander, the Beagle 2, but it was declared lost after it could not be contacted. Both the Express spacecrafts have revealed new information about their respective planets, but until their missions are completed, it remains to be seen which will be hailed the most successful.

© ESA; NASA

# KEY DATES
## SPACE FASHION

**1961** Yuri Gagarin wore the first-ever spacesuit, the SK-1, during his pioneering trip to space.

**1965** The innovative design of NASA's Gemini spacesuit used six layers of nylon for extra protection.

**1969** All 12 astronauts who walked on the Moon used the same Apollo A7L suit design.

**1977** First used in 1977, Russia's Orlan spacesuit continues to be used by cosmonauts on the ISS today.

**1983** NASA's modern Extravehicular Mobility Unit (EMU) spacesuit has been in use since 1983.

**DID YOU KNOW?** In late-2009 a mission was proposed to land a Robonaut 2 unit on the surface of the Moon

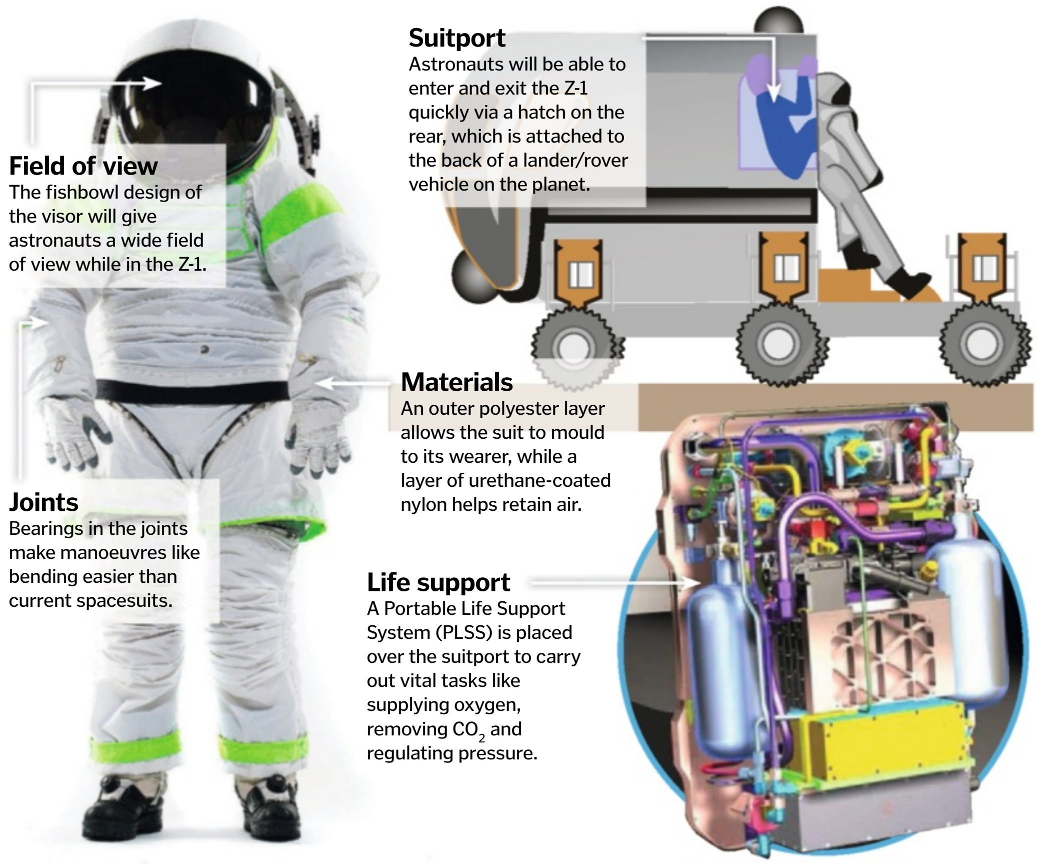
# Inside next-gen spacesuits

What will we be wearing when we one day venture onto the surface of Mars?

When humanity ultimately makes it to the Red Planet or an asteroid, our current spacesuits will not be up to the job. They are too rigid, too bulky and lack the protection required to operate on these distant bodies. With that in mind, NASA has been hard at work on a new spacesuit, known as the Z-1, that has a number of innovations to make such ambitious spacewalks possible.

The major breakthrough in terms of technology is a suitport on the back. Already employed by the Russians on their spacesuits, this enables the wearer to climb quickly in and out of the suit, and also allows the Z-1 to be docked externally on a spacecraft for a quick spacewalk (cutting out the time-consuming pre-breathing procedure which helps prevent decompression sickness). Meanwhile the joints of the Z-1 spacesuit contain bearings that make strenuous movements such as bending down to pick up rock samples much easier.

The Z-1 – planned to be first worn on trips to the ISS in 2017 – is expected to be succeeded by the Z-2, with even more cutting-edge tech. This will be the next step to taking us to previously unexplored locations in the Solar System.




# Robonaut 2 grows legs

Being fitted with a new set of limbs means that NASA's robotic ISS crew member is really going places…

If you took a count of the life forms on the International Space Station (ISS) right now you'd find a total of six humans, but also aboard the orbiting laboratory is the artificially intelligent robot known simply as Robonaut 2.

The robot has been designed to perform tasks autonomously, including general maintenance of the station. Now, though, the latest cargo mission by SpaceX's Dragon capsule, which should have launched by the time you read this, has taken up a pair of climbing legs for the impressive machine.

The main benefit of having legs is that Robonaut 2 will be able to more closely mimic the actions of human astronauts – for example, it can now make use of all the handrails and sockets inside the station to gain greater stability when performing delicate tasks. Small sensors on the feet, called artificial effectors, enable the legs to locate and firmly grip on to structures inside the space station.

The ultimate aim of attaching these extra limbs, however, is that it will allow the robot to operate externally on the station alongside, or perhaps even without, human co-workers. A series of rails and footholds on the exterior of the ISS is vital in order to remain in position during extravehicular activities (EVAs). However, Robonaut 2 won't be sent on any independent spacewalks just yet – not until its upper torso has been further upgraded.

The addition of legs will allow Robonaut 2 to move from working solely inside the ISS to also working outside

© NASA

> "[Star charts] are believed to have been used in primitive form as much as 30,000 years ago"

# Secrets of star charts

## How maps of the night sky have helped us navigate both the cosmos and Earth

Showing the locations of stars, galaxies, constellations and more at any given time of year, a star chart is essentially a map of the night sky. They are believed to have been used in primitive form by our ancestors as much as 30,000 years ago, but over time they have evolved into the detailed specimens we use today.

As Earth rotates on its axis, the positioning of objects in the night sky changes, and thus a star chart will often show the positions of bodies at a specific time of day. However, throughout the course of the year Earth rotates once around the Sun. During this period the objects visible in the sky will vary as the 'night side' of Earth faces a different region of the cosmos. Star charts, therefore, are often created broadly for the four seasons to accurately show the locations of objects at various times of the year. On a star chart you will see a range of useful information, including a line denoting the equator, the motions of other planets in the Solar System and the co-ordinates of a given object in space.

There are several dozen stars in the night sky that are also useful for navigation, and were once used frequently by explorers – particularly when travelling at sea. One of the most famous of these is Polaris – also known as the North Star – and by tracking these cosmic markers our ancestors were able to determine their position on Earth.

### Modern maps

Today many telescopes come with built-in computerised technology that enables them to track and locate celestial objects automatically. This means that, without a chart, we can explore the sky by selecting the object we want to view on the hand controller accompanying the telescope (see image below left). While advances like this are great for convenience, does it mean the age of the star map is over?

Not at all – in fact, star charts are still in constant use. Aside from physical star maps, consulted by astronomers across the world when observing without a computerised telescope, there are a number of apps available for modern smartphones and other gadgets that offer virtual star maps to help amateur stargazers find their way around the night sky.


The light-blue streak across this star chart denotes the Milky Way



### Five famous constellations

**Crux**
One of the most recognisable constellations in the Southern Hemisphere, this group of stars lies on the Milky Way from our view.

**Little Bear**
Ursa Minor, or the Little Bear, is the home of Polaris (the North Star), which can be found at the tip of the Little Dipper 'handle'.

**Orion the Hunter**
Possibly the best-known constellation of all. The orange star to the top-left is Betelgeuse, which could go supernova any day.

**Big Dipper**
Part of the constellation Ursa Major, the Big Dipper is also called the Great Bear and the tip of its 'bowl' points the way to Polaris.

**Great Dog**
Canis Major contains the brightest star in the sky, Sirius (the Dog Star), making it a historically important constellation.

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"Baumgartner wore a modified version of the pressurised suit donned by astronauts at high altitudes"

# Space diving

## There have been two successful jumps from the edge of space, but how can anyone survive such a great fall?

Skydiving is a popular sport for thrill-seekers, but how about diving from the stratosphere? In 2012, Felix Baumgartner set a record by freefalling from 39 kilometres (24 miles) above the Earth. This puts his dive as coming from the stratosphere – not technically outer space, which is usually defined as beginning 100 kilometres (62 miles) above sea level – but who's quibbling? Baumgartner began working with a sponsor in 2005 to plan the mission, recruiting a team that included Joe Kittinger, the first man to dive from the stratosphere in 1960.

Baumgartner wore a modified version of the pressurised suit donned by astronauts and pilots that fly at high altitudes, and rode in a specially built capsule lifted by a high-altitude helium balloon. Pressure suits are necessary at heights above 19 kilometres (12 miles) because the loss of pressure can result in gas bubbles forming in body fluids, leading to a potentially fatal condition called ebullism.

The suit also protected Baumgartner from extremes in temperature on the dive. During the ascent, the capsule provided atmospheric pressure so he didn't get decompression sickness and also shielded him from the extreme cold. Once Baumgartner reached the right height he inflated his suit, opened the capsule door and made the leap. Not only did he break the altitude record, but the sound barrier as well. At 1,524 metres (5,000 feet) above the ground, he deployed his parachute – also designed for high altitudes – after hitting a speed of 1,342 kilometres (834 miles) during his four-minute, 19-second freefall.


## Focus on Felix

Felix Baumgartner is an Austrian daredevil, skydiver and BASE (Building, Antenna, Span and Earth) jumper who has set records throughout his career. Baumgartner served in the Austrian military and learned skydiving as part of their demonstration and competition team before switching to BASE jumping. In 1999, he set a record for the world's highest BASE jump, from the Malaysian Petronas Towers, the tallest buildings in the world at that time at 451m (1,479ft). In the same year he also set a world record for the lowest BASE jump, from the hand of the Christ the Redeemer statue in Rio de Janeiro, which stands just 29m (95ft) tall. Having already worked as a helicopter pilot in Europe, his post-jump plans were to continue on that career path.

# AMAZING VIDEO!

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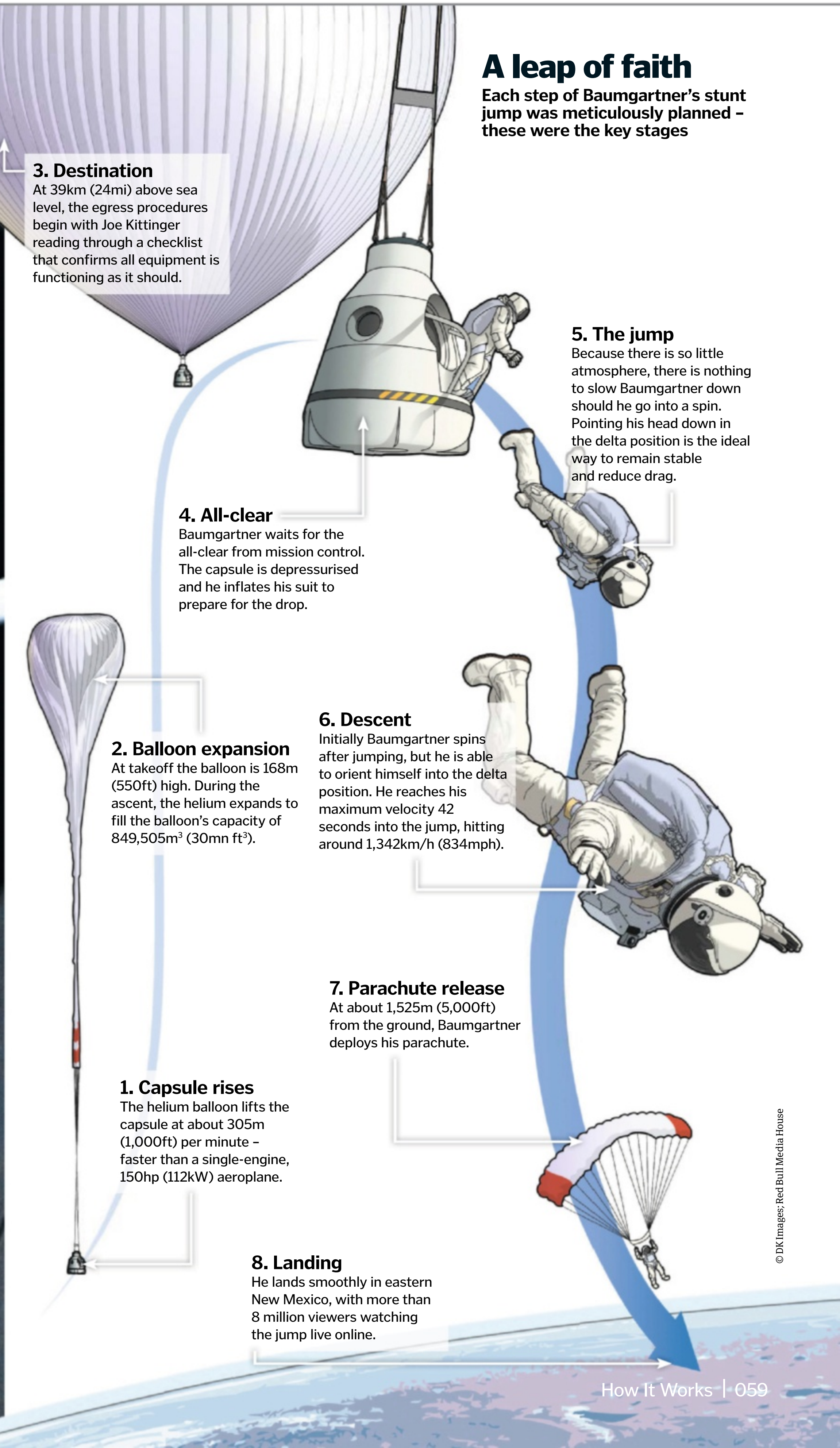
**See what Baumgartner saw on the way down!**

www.howitworksdaily.com



## A leap of faith

**Each step of Baumgartner's stunt jump was meticulously planned – these were the key stages**



### 1. Capsule rises
The helium balloon lifts the capsule at about 305m (1,000ft) per minute – faster than a single-engine, 150hp (112kW) aeroplane.

### 2. Balloon expansion
At takeoff the balloon is 168m (550ft) high. During the ascent, the helium expands to fill the balloon's capacity of 849,505m$^3$ (30mn ft$^3$).

### 3. Destination
At 39km (24mi) above sea level, the egress procedures begin with Joe Kittinger reading through a checklist that confirms all equipment is functioning as it should.

### 4. All-clear
Baumgartner waits for the all-clear from mission control. The capsule is depressurised and he inflates his suit to prepare for the drop.

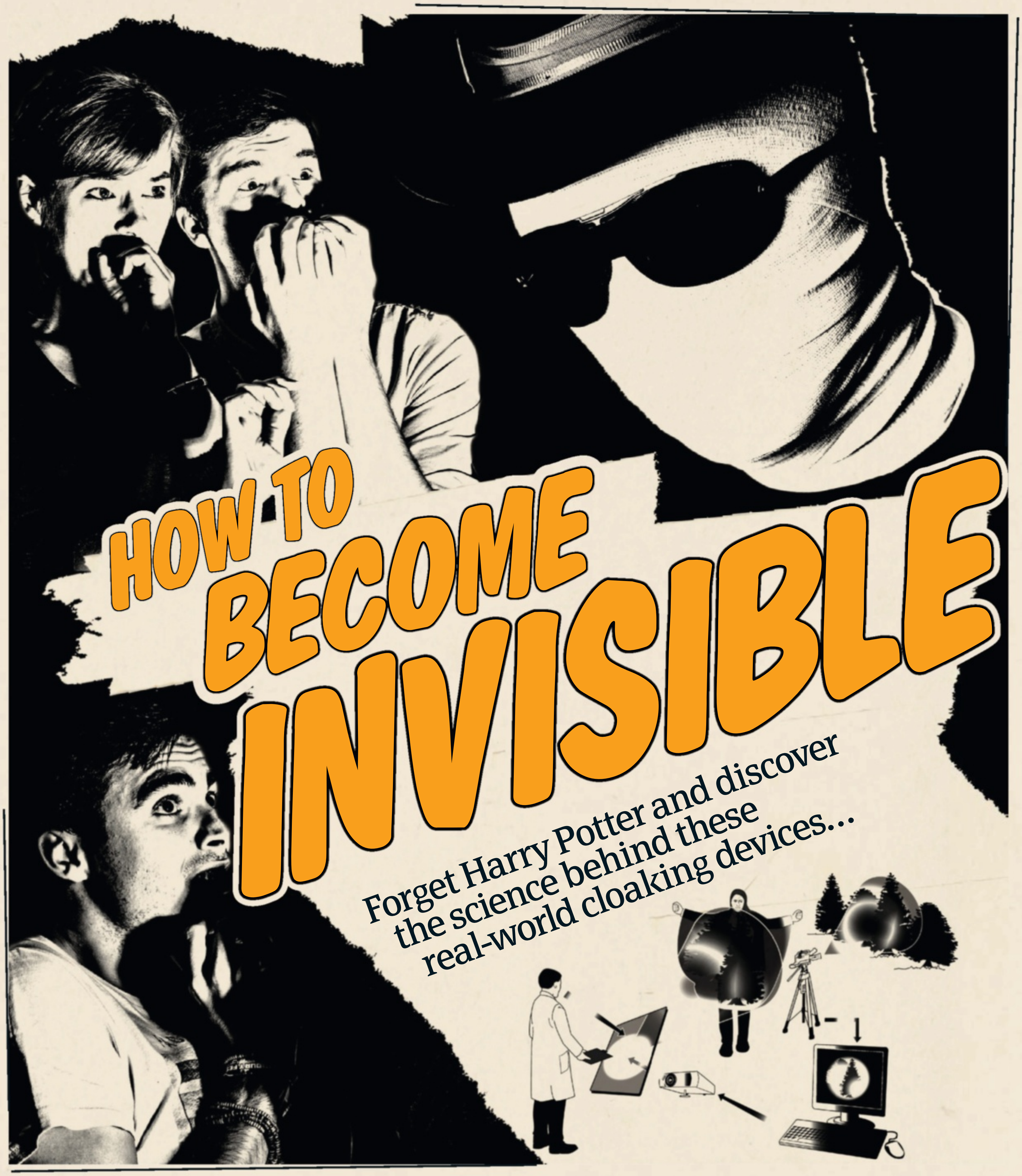
### 5. The jump
Because there is so little atmosphere, there is nothing to slow Baumgartner down should he go into a spin. Pointing his head down in the delta position is the ideal way to remain stable and reduce drag.

### 6. Descent
Initially Baumgartner spins after jumping, but he is able to orient himself into the delta position. He reaches his maximum velocity 42 seconds into the jump, hitting around 1,342km/h (834mph).

### 7. Parachute release
At about 1,525m (5,000ft) from the ground, Baumgartner deploys his parachute.

### 8. Landing
He lands smoothly in eastern New Mexico, with more than 8 million viewers watching the jump live online.

© DK Images; Red Bull Media House

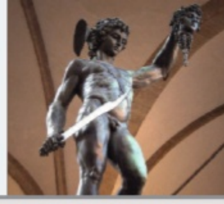


# HOW TO BECOME INVISIBLE

Forget Harry Potter and discover the science behind these real-world cloaking devices…

**For what did Perseus use the Cap of Invisibility?**

A Spying on Athena B Fleeing Gorgons C Stealing olives



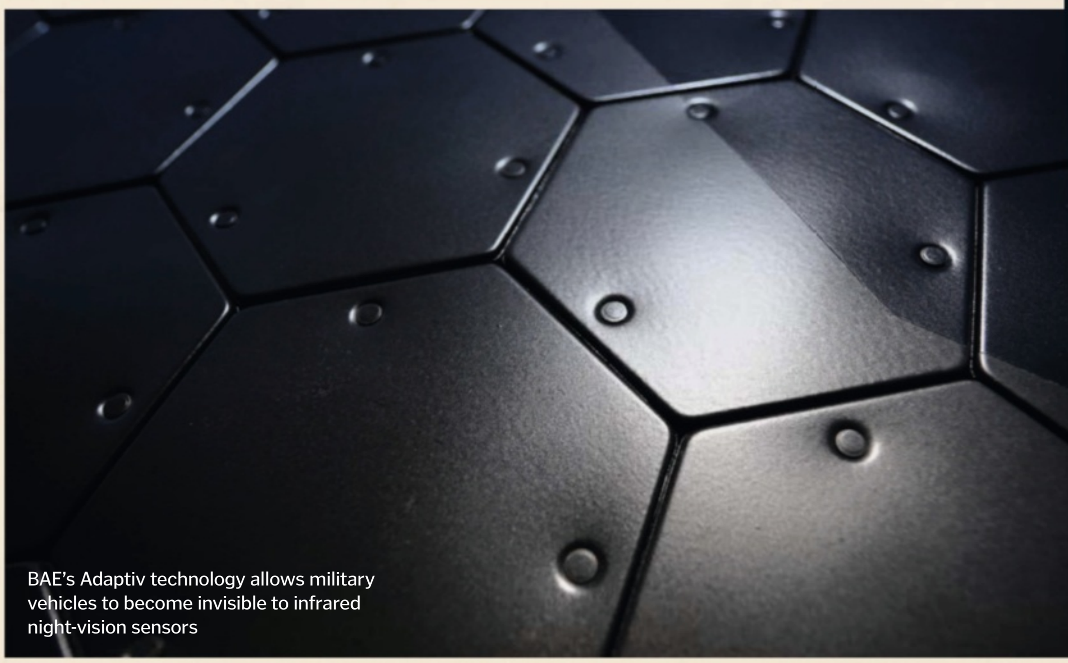
**Answer:**
According to Ancient Greek mythology, Perseus received the Cap of Invisibility, or Helm of Hades, with the help of Hermes and Athena in order to escape the wrath of Medusa's Gorgon sisters, Stheno and Euryale.

**DID YOU KNOW?** Calcite crystal prisms can be used to bend visible light, allowing small objects to be hidden inside

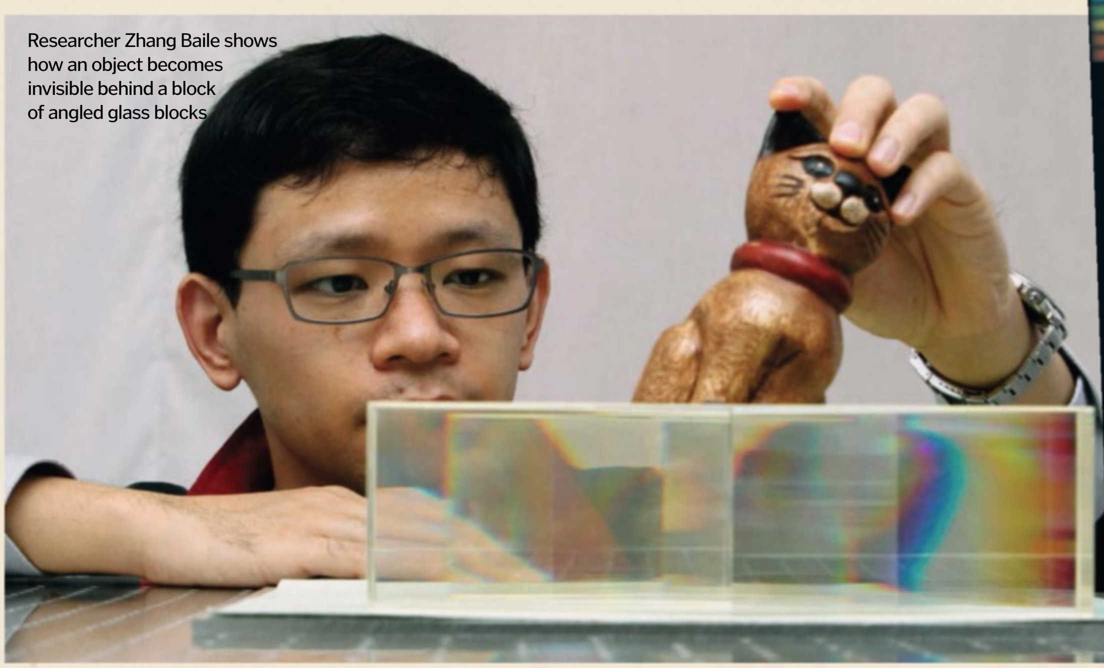
The first step in making something invisible is to understand what makes it visible in the first place. When electromagnetic (EM) radiation hits the surface of an object, one of three things can happen: it can be reflected, refracted or absorbed. Depending on the material, this creates characteristic patterns, detectable by the human eye (if the radiation is within the visible spectrum), or by various electrical equipment.

Essentially, for an object to become invisible, the path of these electromagnetic waves must be disrupted at some point between their source and the detector.

The simplest way to do this is to prevent the reflection of EM radiation entirely, absorbing the energy so that it can't be detected. Plasma stealth is a technique being developed in order to achieve radar invisibility. Plasma is a collection of free-flowing ions and electrons; it interacts with electromagnetic radiation, absorbing and dissipating the energy from incoming EM waves. If a shroud of plasma could be maintained around a plane, it could be used to absorb incoming radio waves, preventing the aircraft from being detected by radar. Unfortunately, plasma emits a visible glow, which would highlight the plane to onlookers. ▶



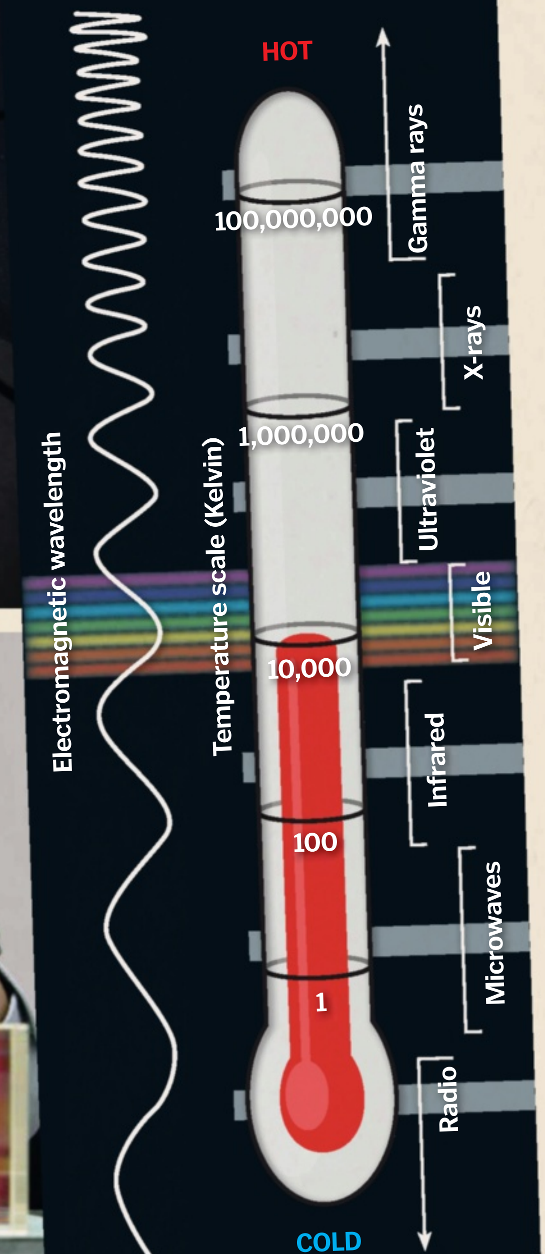
BAE's Adaptiv technology allows military vehicles to become invisible to infrared night-vision sensors



Researcher Zhang Baile shows how an object becomes invisible behind a block of angled glass blocks

## MORE THAN THE EYE CAN SEE...

The electromagnetic (EM) spectrum represents all frequencies of radiation, from the longest radio waves to the shortest gamma rays. The human eye is only capable of detecting light in the visible part of the spectrum, which covers a narrow range of wavelengths, roughly 400-700 nanometres in size. The reason for this is the Sun. Eyes capable of detecting X-rays would not be very useful on Earth because most of the EM radiation emitted by the Sun is in the visible, UV and IR parts of the spectrum. Further, UV radiation is absorbed by the ozone layer, and infrared light by water vapour in the air. So, for seeing, light in the visible spectrum makes the most evolutionary sense.



*"The most promising invisibility cloaks actually bend light, preventing it from hitting the concealed object at all"*

Light absorption can also be used to make objects invisible to the human eye. For instance, NASA has developed a coating made using carbon nanotubes, capable of absorbing 99 per cent of the EM radiation in the ultraviolet, visible, infrared and far-infrared parts of the spectrum. Objects painted with the nanotubes are intensely black, and the technology has significant potential for hiding vehicles in the blackness of space.

Unfortunately, most of the time there is enough light that painted objects would be conspicuously dark on Earth. A better technique is to use optical camouflage to closely mimic the surroundings. Using a camera to record the background, in conjunction with a projector to display the images, a version of a Harry Potter-style invisibility cloak is another technology currently under development.

Due to its design, at the moment the illusion only works from one angle. The projected image must strike the cloak head-on, and must reflect straight back into the eyes of the viewer, as though it were coming from the background itself. This is achieved using beads of retro-reflective material. Normally, rough surfaces scatter light in all directions, while mirror-smooth surfaces reflect it back at an angle, but the beads behave differently. They act as miniature prisms, bending the light as it enters and reflecting it back in exactly the same direction that it came in. Despite its flaws, the technology does have other potential applications, including allowing pilots to see through the floor of their aircraft – which would be very helpful when coming in to land.

The most promising invisibility cloaks actually bend light, preventing it from hitting the concealed object at all. Every material has an index of refraction – a number that represents the speed of light travelling through the material, relative to the speed of light in a vacuum. Natural materials, including air and water, all have a positive refractive index; that is, light travels more slowly through them than it does through a vacuum.

As light crosses from one material to another, a change in refractive index causes it to change direction. If the refractive index changes abruptly – for example, as light passes from water to air – the light is refracted and changes direction. If the refractive index changes more gradually, the light bends in a curve.

This is not so unusual as it sounds. In a desert, the scorching sand heats the air near to the ground, creating a temperature gradient, which in turn creates a gradient in the refractive index of the air. As light passes through this gradient, it bends upwards, generating the illusion that a wet puddle of sky is in the ground. By mimicking the conditions that create such a mirage, it is possible to hide objects by bending light away from them.

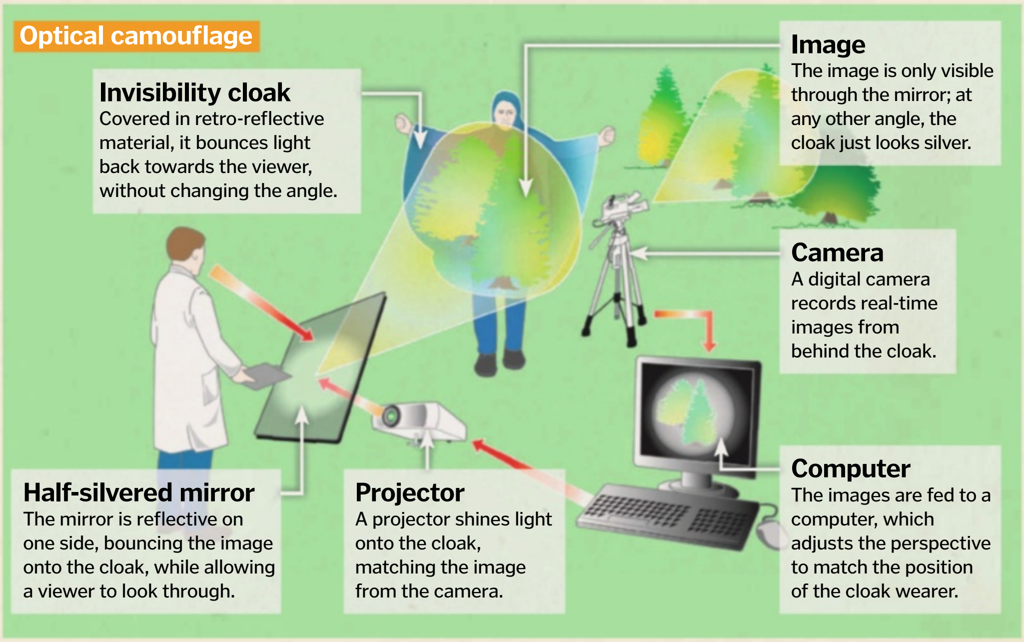
Carbon nanotubes are single-thickness tubes of graphene and one of a host of cutting-edge smart materials. They are highly conductible and can be heated and cooled rapidly. If a sheet of these nanotubes is heated in water using an electrical current, it is possible to mimic the effect of a mirage in the desert. As the current passes through the sheet, the water near to it is heated too, so the light bends, making it disappear. However, despite being impressive to watch (check out the video opposite), this technique only works underwater so far.

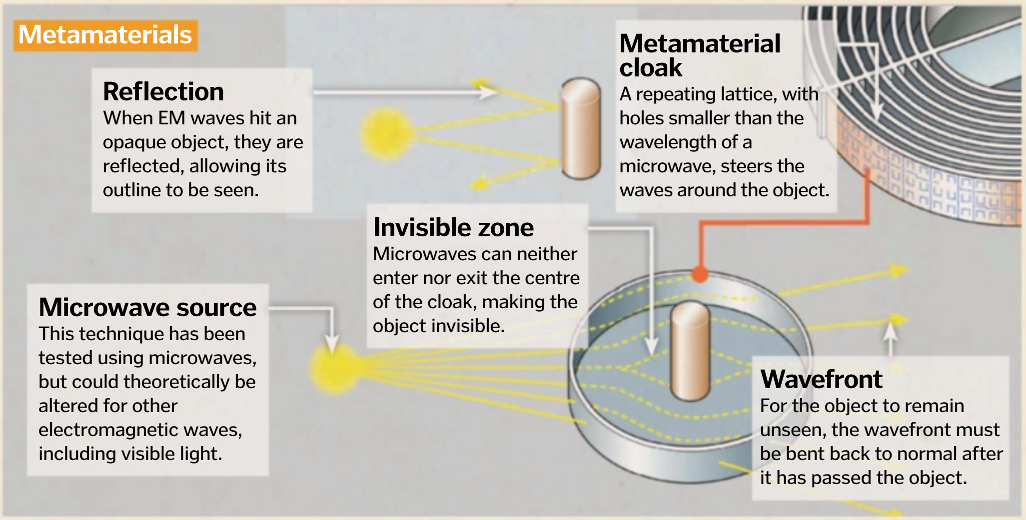
Using the mirage phenomenon for invisibility has its limitations, but specially designed materials allow electromagnetic radiation to be bent in a more controlled way. Metamaterials have a negative refractive index, which makes them capable of bending EM radiation. Using a ring constructed from lattice-shaped metamaterials, microwaves can be bent around a small object, rendering it invisible.

In order for this to work, the wavefront must look exactly the same when it enters the cloak

## FOUR WAYS TO PERFORM A VANISHING ACT

**By manipulating the electromagnetic spectrum, a variety of 'invisibility' cloaks have been invented. See how each of them works in these quick guides**



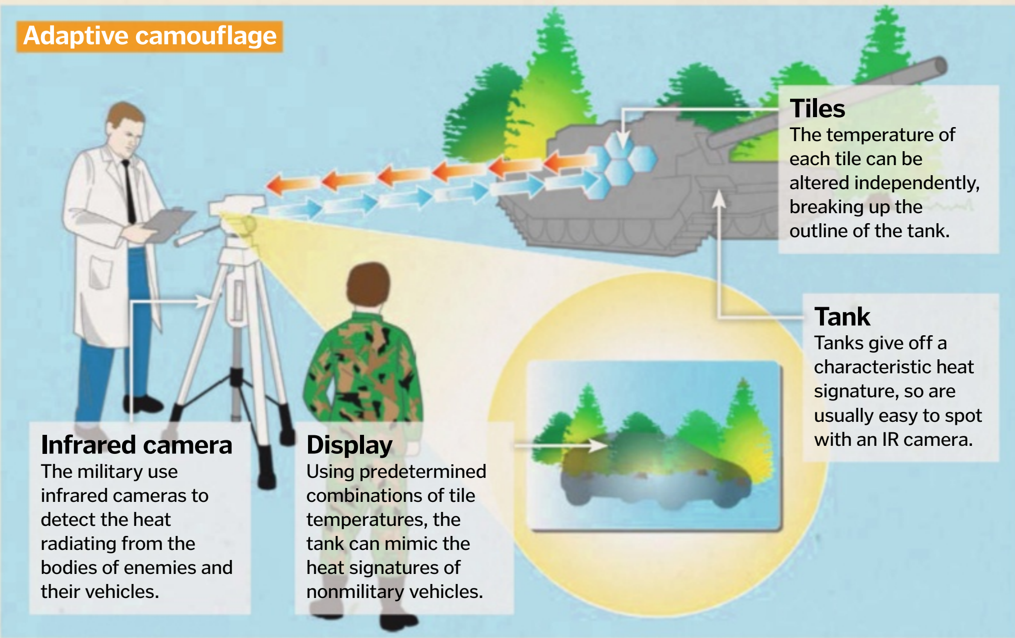
**DID YOU KNOW?** Metamaterials could be used to create a perfect microscope lens, as they do not diffract light

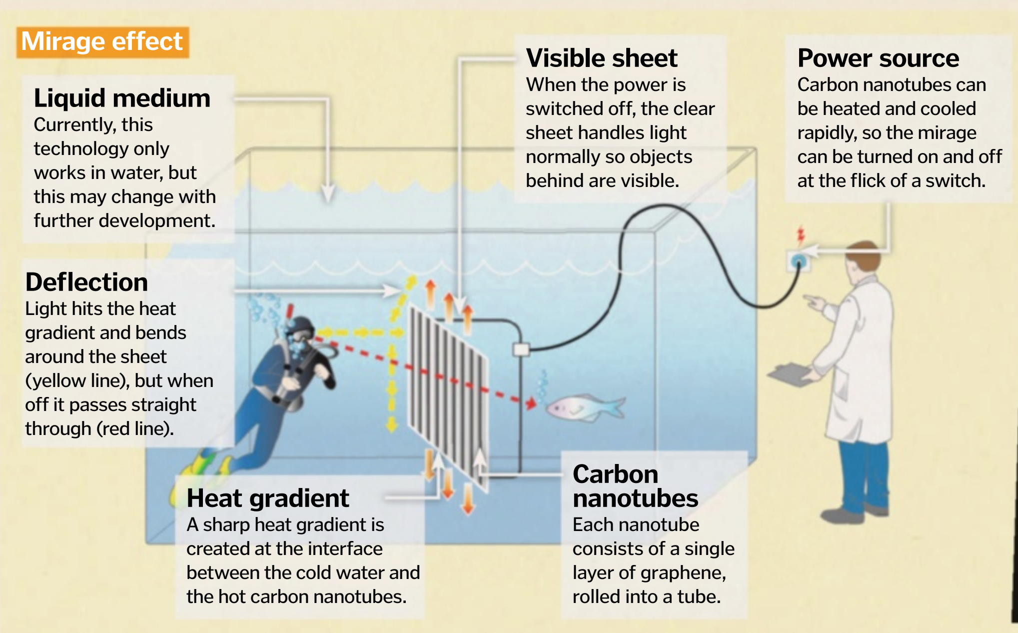
as when it leaves. However, curving EM radiation around the object means different waves must travel different distances to get through. If the wave travelling the shortest distance is moving at the speed of light, then the other waves must be moving faster.

Surprisingly, this is not against the laws of physics, which state that information cannot be transmitted faster than the speed of light. As long as only a single wavelength is travelling through the cloak, no new information is being transmitted, so the waves can move at different speeds and then converge at the other end.

This makes translating the technology to the visible spectrum much more challenging. A cloak capable of bending just one wavelength would mean that only a single shade of a particular colour would be invisible to the eye. Even if it were possible to bend all wavelengths in the electromagnetic spectrum at once, this would mean that no light could enter the centre of the cloak, so although you might be invisible, you wouldn't be able to see out either.

Unfortunately, soft, flexible and wearable Harry Potter-style invisibility cloaks that work in the visible spectrum are still some way off. However, invisibility technology has great potential for use in other areas, from disguising fighter jets to making internal organs see-through during surgery.




## THE ULTIMATE STEALTH TECHNOLOGY IN FOCUS

The military uses infrared cameras to detect the heat signatures of enemy vehicles and personnel, so by disrupting the profile of heat given off by a tank, it can be hidden from view.

The vehicle is covered in honeycomb-shaped panels, each of which can be individually cooled to alter its temperature. Not only does it allow a tank – or potentially other vehicles like helicopters – to blend in with the temperature of its surroundings, but the plates can project alternative 'images'. By altering the temperature of the tiles, the heat signatures of other objects can be mimicked, disguising the tank as something innocuous like a small family car.

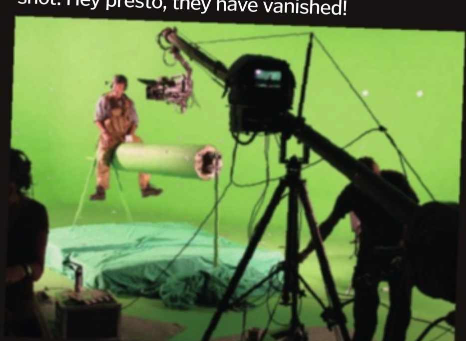
An entire tank can now be made invisible to infrared sensors

## INVISIBILITY IN THE MOVIES

Creating invisibility cloaks for films is simpler than creating them in real life. Known as chroma-keying, the technique involves layering images on top of one another to create a composite.

The most familiar use of this technology is green or blue screens. An actor is filmed in front of a solid-colour background and the image is then processed, removing everything within the colour range of the background and rendering it transparent. This image is then layered on top of the desired background footage, giving the illusion that the actor is part of the virtual scene.

Usually, actors avoid wearing clothing in the same colour key as the background, as it would result in parts of their outfit disappearing in processing. But for invisibility cloaks, this is the desired effect. By wearing a block-coloured cloak, the actor can effectively be removed from the shot. Hey presto, they have vanished!



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"The majority of stem cells are contained in the red marrow"

# Inside our bones

## Learn how bone marrow can transform cells into whatever the body needs

The skeleton is not only used as the body's main structural support, it is also home to the largest collective reserve of adult stem cells within us.

Bone marrow is a soft tissue present inside all the long bones of the limbs, and inside flat bones such as the pelvis, skull and ribs and it is jam-packed woth haematopoietic stem cells. These cells are only partly committed to their development pathway, so depending on the signals they receive, can become any of the cells in the blood, from oxygen-carrying red blood cells to bacteria-munching macrophages.

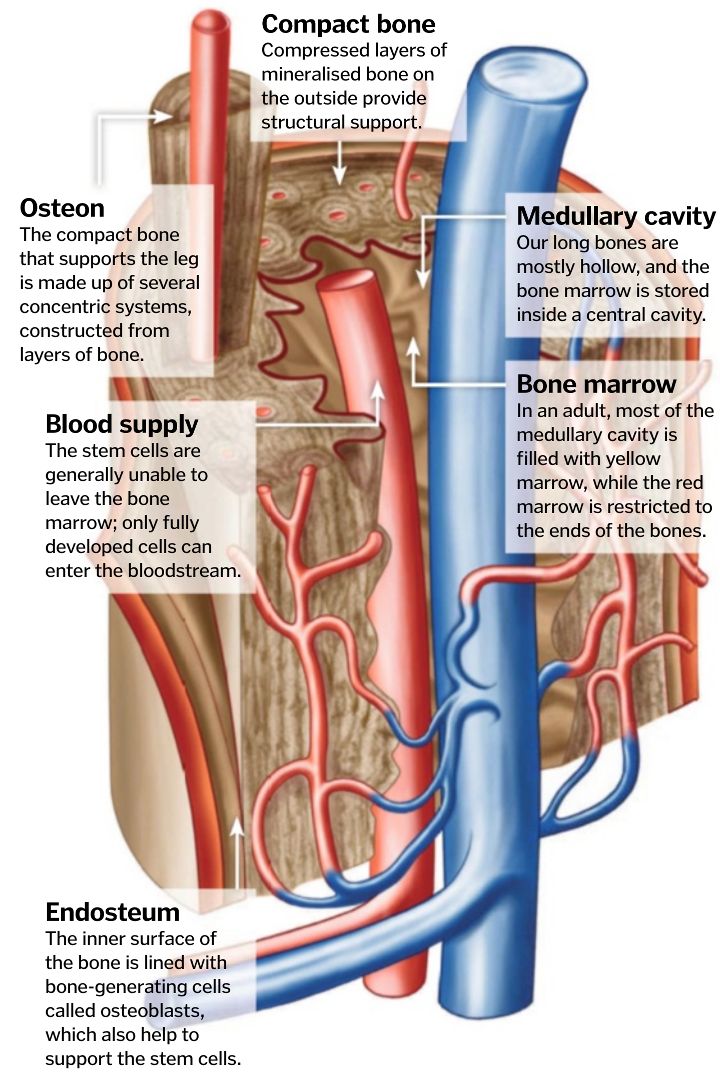
The majority of these stem cells are contained in the red marrow, which gains its colour from a rich network of blood vessels. The stem cells are supported by a range of other cells collectively known as stroma. The stromal cells provide the right microenvironment for the development of stem cells into the blood's components, making a range of growth factors to encourage cells to differentiate down the correct path.

In an adult human, most of the long bones are filled with yellow bone marrow – mostly made up of fat cells – however this can be converted to red marrow for blood cell production should an emergency arise.

Bone marrow also contains a second, less-studied population of stem cells known as mesenchymal stem cells (MSCs). These are able to produce the basic elements that make up the connective tissues of the body, including fat cells, bone cells and fibroblasts.

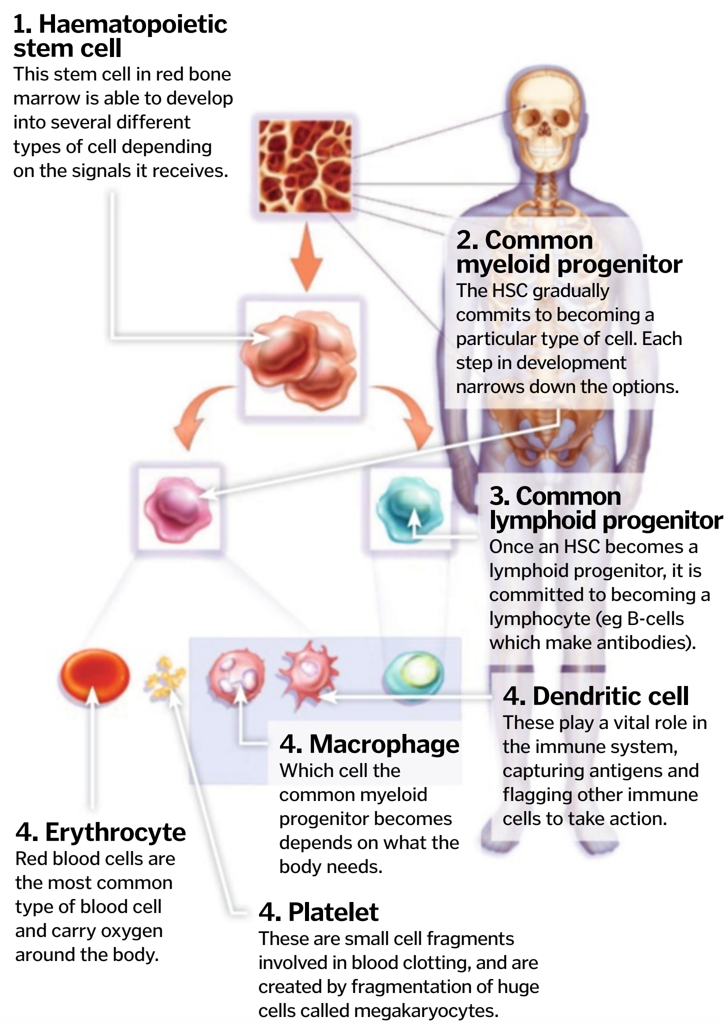
## Bone marrow in context

**What is going on inside one of the long bones in our legs?**




## The origins of blood

**See how bone marrow is a factory capable of producing all of the components which make up our blood...**

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"The first priority is to stop the burning process; cold running water is often the best first treatment"

# What happens when we burn ourselves?

## Burns range from irritating to life-threatening – learn about the different types now

Most people associate burns with flames, but they have many other causes. A burn is medically defined as 'coagulative destruction' of the skin, meaning any energy source can cause one. This energy damages underlying skin proteins and fat cells, causing breaks in the continuity of the skin.

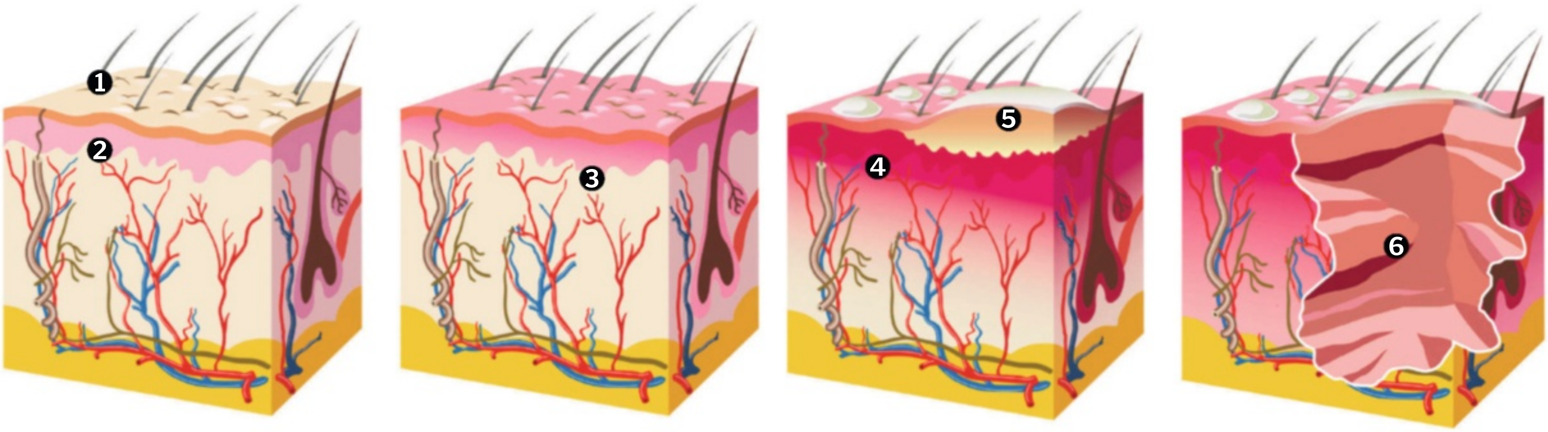
Burns are generally classified by their depth. First-degree (superficial) burns leave painful, red skin, but without large blisters. Only the epidermis is damaged, so regrowth is fast. Second-degree burns (partial thickness) can be either superficial or deep. The skin usually blisters and can be very painful. The dermis layer is also damaged so regrowth is slow, taking several weeks or even months. In third-degree burns (full thickness) the skin is left white or pale, with no blistering and little to no sensation. The basal growth layer is destroyed so no new skin can grow.

Even minor burns can cause problems if not treated properly. The first priority is to stop the burning process; cold running water is often the best first treatment. Infection, dehydration and protein loss are all problems that occur next, which our resilient skin can solve itself if the injury isn't too severe.

Indeed, first and second-degree burns will generally heal themselves over time, though there may be some permanent scarring. Full-thickness burns don't heal, so skin grafts, taken from other parts of the patient's body, are needed in these severe cases.

### How burns are measured

**Classified by their depth, each burn case requires unique treatment**




**1 The skin**
Your skin is vital to your wellbeing. It has multiple important functions, including temperature control, sensation and appearance.

**2 Basal layer**
This layer is the key to regeneration, as new skin cells grow from here. If undamaged, regrowth occurs without any need for medical assistance.

**3 First-degree burn**
Only the uppermost skin layers (known as the epidermis) are affected, but the burn is painful, leaving the area red, raw and tender to the touch.

**4 Second-degree burn**
These partial-thickness burns affect the upper or deep dermal layers, and like first-degree burns hurt a lot because the nerve endings remain active.

**5 Blisters**
Blisters appear when the epidermis separates from the dermis, and are especially common in first and second-degree burns.

**6 Third-degree burn**
Deep burns destroy the basal layer and nerve endings, so they are painless. Regrowth will not occur alone, so skin grafts are needed.

### Four major causes of burns

**Thermal**
Heat can come from a flame or friction (known as dry burns), hot liquids that cause scalds (known as wet burns) or direct contact with hot surfaces.

**Chemical**
Alkalis (like bleach) burn for hours, whereas acids are short-lived. These require no heat to cause a burn, and can take some time to develop after skin contact.

**Radiation**
Ionising radiation burns can be widespread across the body due to exposure. Sunburn is a common type of radiation burn, caused by exposure to ultraviolet radiation (UV) in sunlight.

**Electrical**
These often cause deep burns that heal very slowly. A small skin defect may mask deep underlying damage, which can extend throughout the entire body.


A second-degree burn will heal itself over time but probably leave scars

© Thinkstock

## HEAD 2 HEAD
### NATURAL SEDATIVES

**1. STRONG**

**Chamomile**
This sweet-scented daisy-like plant is used to treat mild anxiety. The compounds in it bind to the same brain receptors as drugs like Valium.

**2. STRONGER**

**Hops**
We mainly think of it as an ingredient in beer, but you won't get its sedating effects from a pint. The active compounds are found in its oils.

**3. STRONGEST**

**St John's wort**
St John's wort is frequently used to treat depression and studies have found the plant to be just as effective as standard antidepressants.

**DID YOU KNOW?** *Asbestos is naturally present in the air and some drinking water*

# How do tranquillisers work?

## Discover how these drugs relieve anxiety and why they can also make us drowsy

Tranquillisers are drugs that suppress the central nervous system and slow the body down. There are two types: major and minor. Major tranquillisers are used to treat patients with severe mental illnesses and alleviate delusions and hallucinations. Phenothiazines are the most widely used and include chlorpromazine. Blocking the neurotransmitter dopamine in the brain, they reduce psychotic symptoms but can produce side effects like tremors and spasms.

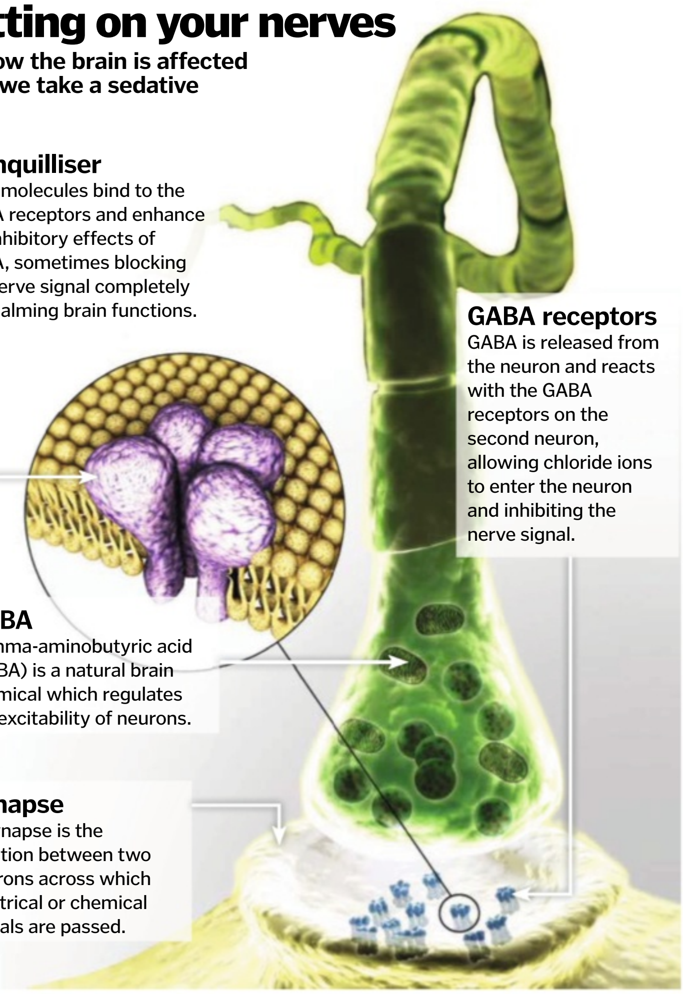
The most common minor tranquillisers, meanwhile, are benzodiazepines, which include diazepam, chlordiazepoxide and alprazolam. These drugs have a calming effect and reduce anxiety and fear. Because of this, benzodiazepines are among the world's most widely prescribed drugs. They enhance the action of the neurotransmitter gamma-aminobutyric acid (GABA), which prevents anxiety by reducing nerve-impulse transmissions in the brain. It is by depressing the part of the brain that controls activity that tranquillisers make us drowsy or, with stronger variants, can knock us out altogether.

### Sedatives for animals

The conservation of wild animals often involves their relocation or medical treatment. Both are very stressful events, which may cause them to injure themselves or the people involved. Tranquillisers relax and calm the animals, leading to an indifference to their surroundings and a loss of fear of humans. But different drugs have different effects between species, so a drug that's safe and effective on one creature may be harmful to another. For example, midazolam sedates guinea pigs and rabbits, but can have the opposite effect on cats and dogs. It is therefore important that the correct drug and dosage are used.

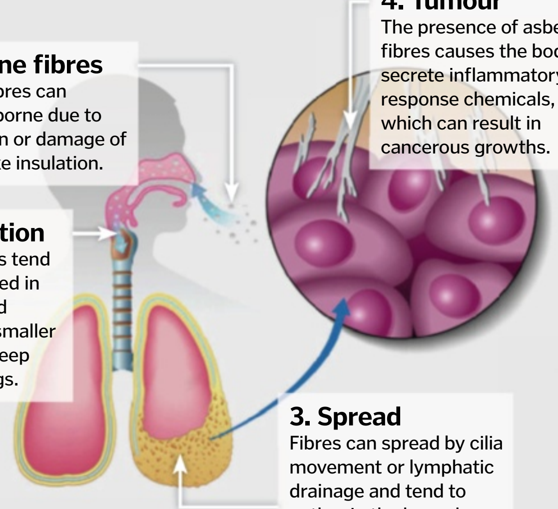
## Getting on your nerves

**See how the brain is affected when we take a sedative**




## Asbestos in the lungs

**What happens when we inhale this mineral?**




# What is asbestos?

## The miracle material with a deadly secret

Since its discovery over 4,000 years ago, asbestos has been considered a miracle material with limitless uses, combining the strength of rock with the flexibility of silk. It is a naturally occurring mineral found in metamorphic and igneous rocks. It's unlike other minerals in that its crystals take the form of long, thin fibres that are strong, flexible, non-flammable and acid-resistant, making it seemingly perfect for use in construction. Asbestos was widely used in buildings from the Fifties to Eighties for insulation, flooring and roofing. However, in the Seventies health problems linked to asbestos surfaced and it was discovered that breathing in asbestos fibres can cause a number of fatal lung diseases, including mesothelioma and lung cancer, which can take many years to develop. Though the use of brown and blue asbestos was banned completely in 1985, an average of 20 tradesmen still die each week as a result of asbestos exposure.

© Thinkstock; Corbis

*"The tension rapidly transforms this tiny hole into a big tear, ripping the balloon apart with an almighty bang"*

The shockwaves created by a bursting balloon are made visible in this high-speed photo by adding talcum powder

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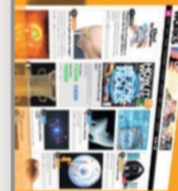
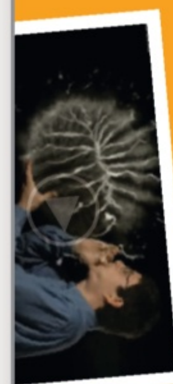




DID YOU KNOW? Helium molecules slip through the tiny gaps in stretched latex; that's why helium balloons are usually made of foil

# Balloon-popping science

Find out why the properties of latex give bursting balloons their bang

Balloons are made of latex, a special type of polymer called an elastomer. If you were to look at latex under a powerful microscope you would see a tangle of long molecules resembling a plate of cooked spaghetti. Each molecule is linked to its neighbours by bonds called cross-links, forming a dense network. When pulled apart, these tangled molecules straighten out, but as soon as the tension is released they snap back to their original shape, lending latex its stretchy quality.

Inflate a balloon and the latex molecules stretch out, putting the balloon's skin under a large amount of tension. If you then jab the balloon with a needle, you create a tiny fault in the latex. The existing tension rapidly transforms this tiny hole into a big tear, ripping the balloon apart with an almighty bang.

Don't feel embarrassed if popping balloons make you jump – their deafening noise is caused by nothing less than a sonic boom. As the balloon tears, the resulting pieces of latex contract at great speed. The ends of each piece move so fast that they break the speed of sound in latex, sending a shock wave travelling through the material.

Sharp objects aside, any process that creates a weak point somewhere on the balloon makes it liable to pop, from a naked flame to a tiny spark caused by static electricity discharging. Latex also becomes weaker and stiffer over time, allowing faults to develop gradually. This explains why balloons sometimes seem to mysteriously burst of their own accord.

## No bang theory

It might seem illogical but there is a way to pierce a balloon without it popping – discover how in this step-by-step…

**1. Inflate the balloon**
For this trick, use a good-quality, medium-sized balloon. Take a deep breath and inflate the balloon to full size – stretching the latex a little beforehand makes this easier. Then let out about a third of the air and tie a knot.

**2. Prepare a skewer**
Take a wooden skewer, making sure to pick a sharp one with no splinters which could tear the balloon. Dip the tip of the skewer in vegetable oil, which will act as a lubricant to reduce friction and help the point glide through the balloon's skin.

**3. Pierce the balloon**
Start at the bottom (beside the knot) as this is where the balloon's polymer molecules are stretched the least. Carefully push the skewer into the balloon where the rubber looks darkest. Gentle pressure will help, but don't jab yourself!

**4. Out the other side**
Gently push the skewer through the balloon, guiding it toward the opposite end. The latex here is also under less tension than elsewhere, so it can be pierced without bursting the balloon. Push the skewer until it emerges through the skin again.

**5. Take a bow**
Job done – although you should expect the trick to take a few attempts before you get it right. You can now remove the skewer from the balloon if you wish – it still won't pop at this stage but the air inside the balloon will leak out fairly fast.

© Alamy

# Buckingham Palace uncovered

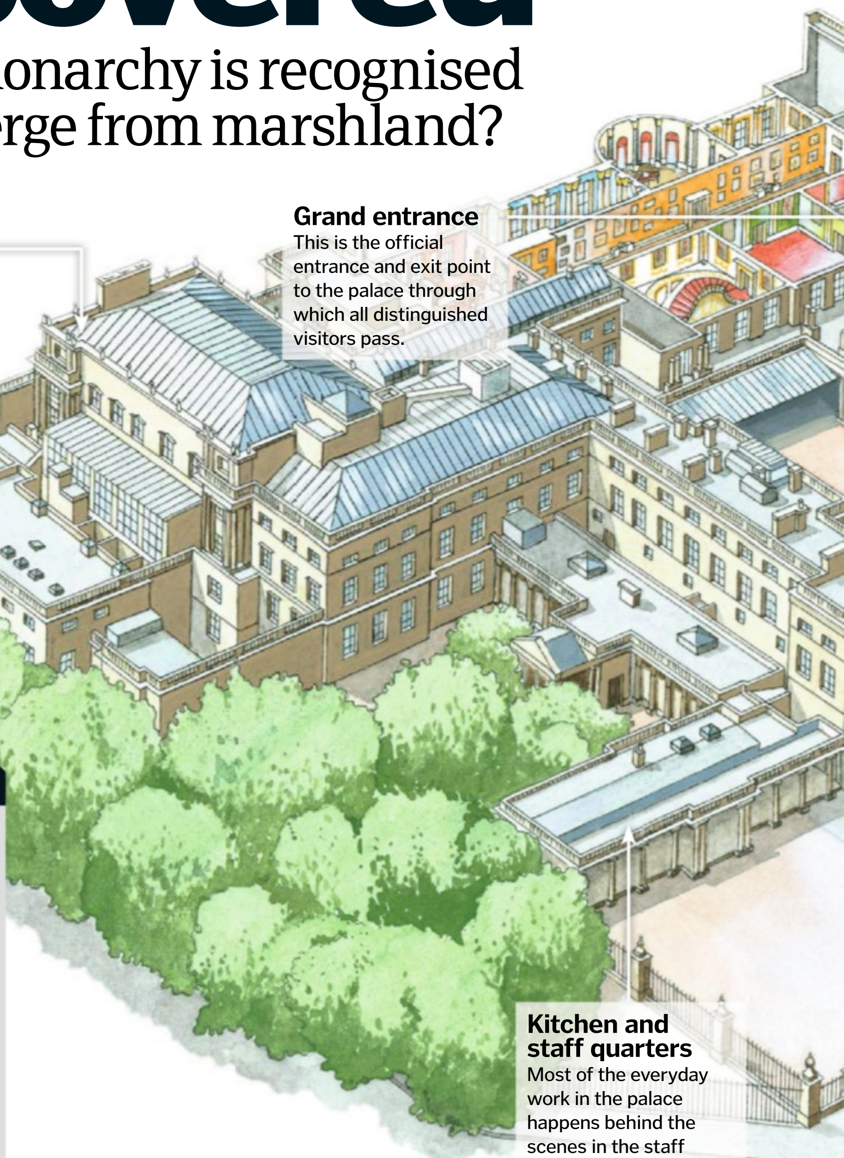
## The London home of the British monarchy is recognised the world over, but how did it emerge from marshland?

Although one of London's most popular historic landmarks, Buckingham Palace as we know it today is less than 200 years old. Part of the medieval manor of Ebury, the land on which the palace stands, came into royal possession under Henry VIII.

Planted up as a mulberry garden by King James I (1603-1625) in an attempt to rear silkworms, the site of the future palace passed through various hands before Goring House, Arlington House and then Buckingham House were built on the same site in less than 150 years. Little is known about these houses, but they are thought to have stood where the south wing of the palace is located today.

In 1761 George III purchased Buckingham House for his wife, Queen Charlotte, as a quiet family home close to St James's Palace. A rather simple redbrick building, the king remodelled the house in 1762 and it was redesigned again on the accession of George IV in 1820. In 1826 the king decided to transform the old-fashioned house into a palace. The celebrated architect John Nash doubled the size of the building by adding a new suite of rooms in a French neoclassical style. The north and south wings of the old house were demolished and rebuilt on a larger scale, with a triumphal arch – the Marble Arch – as the courtyard's centrepiece.

With the accession of William IV, Nash was replaced by Edward Blore who finished work on the palace. The king, however, did not care for the building, failed to move in and even offered ▶



### State ballroom
The largest room in the palace, the ballroom was added by Queen Victoria in 1854. It is 37m (121ft) long, 18m (59ft) wide and 13.5m (44ft) high.

### Grand entrance
This is the official entrance and exit point to the palace through which all distinguished visitors pass.

### Kitchen and staff quarters
Most of the everyday work in the palace happens behind the scenes in the staff quarters. They are located all around and even under the palace.

### The statistics…

*Buckingham Palace*

**Architects:** John Nash, Sir Aston Webb, Edward Blore and others

**Built:** 1762-1914

**Area:** 77,000m² (830,000ft²)

**Height:** 24m (79ft)

**Number of rooms:** 775

**Cost:** Estimated at over £1bn ($1.7bn) today

## The palace over time

**Take a tour through Buckingham Palace's history and discover the key events that made it the landmark it is today**

### 1536
**Land sold**
King Henry VIII takes the Manor of Ebury, which includes the land where the palace now sits, off Westminster Abbey and leases it to royal landlords.

### 1624
**First house built**
Sir William Blake builds the first house on the site. Bought by Lord Goring in 1633, the original structure is extended and becomes known as Goring House.

### 1674
**Fire!**
Purchased by Henry Bennet, First Earl of Arlington, Goring House burns down in 1674. Its replacement is called Arlington House.

# 5 TOP FACTS
## ROYAL RESIDENTS

**Queen Elizabeth II**
1 The palace is the Queen's London home. Inhabiting her own quite modest private apartments, she is usually absent during August and September each year.

**The corgis**
2 The Queen has two corgis, Holly and Willow, and two 'dorgis' (corgi/dachshund crosses), Candy and Vulcan. The royal corgis travel with her throughout the year.

**Queen Victoria**
3 Britain's longest-reigning monarch, Victoria improved the palace by adding the east wing and state ballroom, but after Prince Albert's death in 1861, she rarely visited it.

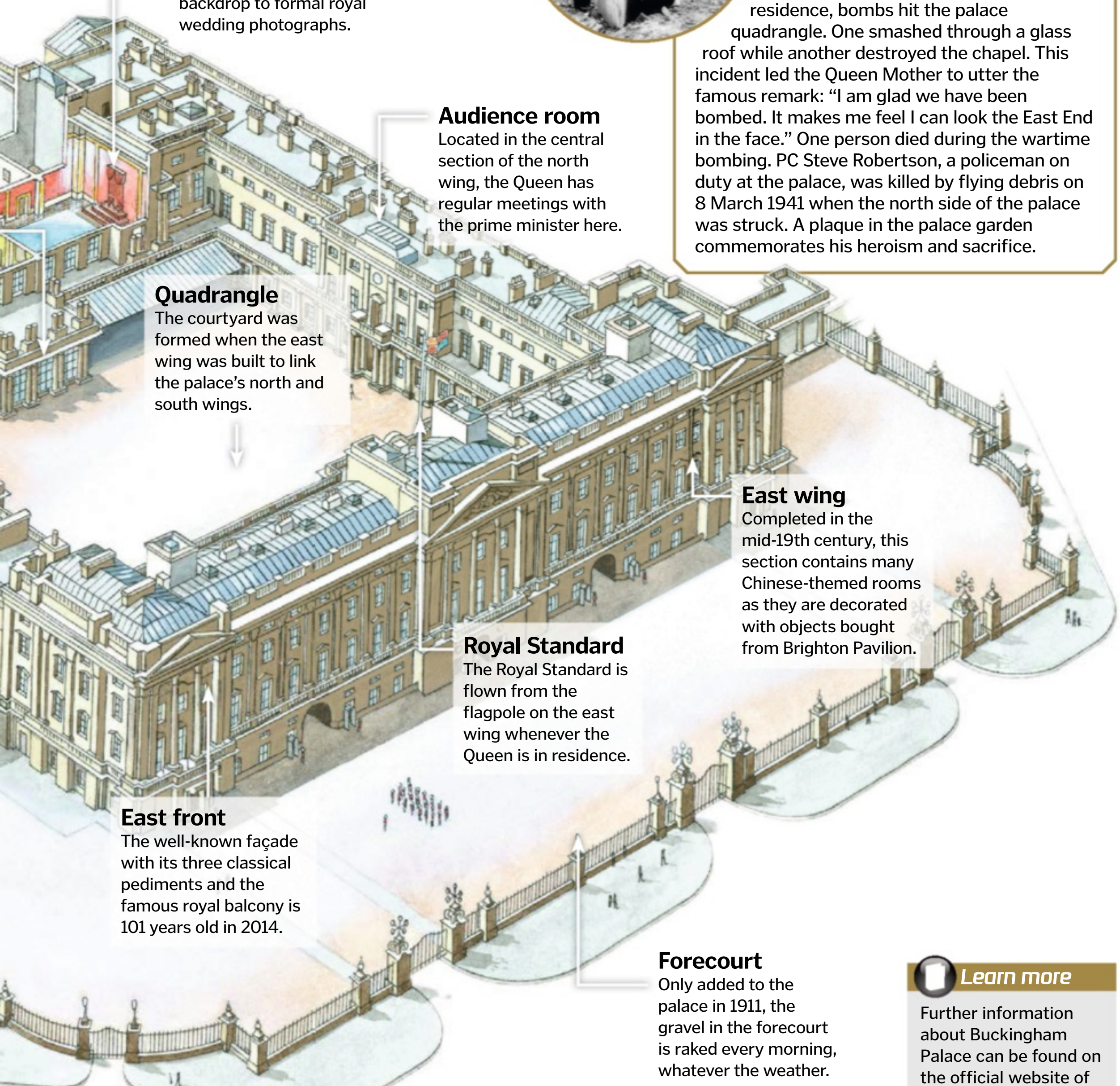
**Duke of Edinburgh**
4 Since his marriage to Queen Elizabeth in November 1947, Prince Philip has lived alongside her at Buckingham Palace. He has his own private office and apartments.

**King Edward VII**
5 King Edward VII is the only monarch to date who was both born and died at Buckingham Palace. The king was born there in 1841 and passed away in 1910.

**DID YOU KNOW?** *There are over 350 working clocks and watches in Buckingham Palace, one of the world's largest collections*

## Under fire

The palace suffered nine direct hits from bombs in WWII, but suffered little damage. However, on 13 September 1940, when King George VI and Queen Elizabeth the Queen Mother were in residence, bombs hit the palace quadrangle. One smashed through a glass roof while another destroyed the chapel. This incident led the Queen Mother to utter the famous remark: "I am glad we have been bombed. It makes me feel I can look the East End in the face." One person died during the wartime bombing. PC Steve Robertson, a policeman on duty at the palace, was killed by flying debris on 8 March 1941 when the north side of the palace was struck. A plaque in the palace garden commemorates his heroism and sacrifice.




**Learn more**
Further information about Buckingham Palace can be found on the official website of the British monarchy: **bit.ly/1mLj944.**

## 5 other royal pads

**1 Windsor Castle**
The Queen's official residence and the largest occupied castle in the world. Inside the walls is St George's Chapel, home to the Knights of the Garter and the burial place of ten British monarchs.

**2 Sandringham House**
The private home of the sovereign since 1862. The royal family usually spend Christmas here and stay until February each year.

**3 Palace of Holyroodhouse**
The Queen's official residence in Scotland, founded as a monastery in 1128. Situated at the end of the Royal Mile in Edinburgh, the Queen is usually in residence for a week at the end of June each year.

**4 Clarence House**
Built in the early-19th century. The Queen lived at Clarence House after her marriage to the Duke of Edinburgh in 1947. Today it's the official home of the Prince of Wales, the Duchess of Cornwall and Prince Harry.

**5 Balmoral Castle**
The Queen's private home in the Scottish Highlands, the Balmoral estate was bought and the present castle built by Queen Victoria and Prince Albert around 1850.

**1703**
**Buckingham House is built**
The house forming the core of the present palace is made for the Duke of Buckingham by architect William Winde.

**1761**
**Royal residence**
George III buys Buckingham House for his wife, Queen Charlotte, as a family home close to St James's Palace.

**1762**
**Extreme makeover**
King George III employs Sir William Chambers to completely remodel the now old-fashioned house, at a cost of £73,000 – a huge sum in the 18th century.

"The palace has its own chapel, post office, swimming pool, doctor's surgery and even a cinema"

it to Parliament as their new home after the Palace of Westminster (the Houses of Parliament) was destroyed by fire in 1834. But Queen Victoria decided to make Buckingham Palace her home and, after moving into the house in 1837, decided to have it enlarged as the palace had too few bedrooms for visitors and no nurseries. Blore designed a new east wing and had the Marble Arch moved to its present home at the north-east corner of Hyde Park. The east wing was constructed using French stone and was the last major addition to the palace.

This was not the end of construction work. In 1911, the present forecourt was formed with its impressive gates and railings, where the changing of the guard takes place today (see boxout). Just two years later the stone on the east wing's façade was discovered to have deteriorated so badly due to London's polluted atmosphere that it needed to be replaced. Sir Aston Webb produced a new design and, after a year of preparation, the new Portland stone façade was erected in just 13 weeks.

The palace's most impressive rooms are the state rooms, most of which are in the west wing. These consist of a sequence of theatrically magnificent interiors, designed to impress visitors and magnify the glory of the British monarchy. The state rooms are reached by ascending the grand staircase. The throne room, the blue drawing room and the white drawing room are the principal reception rooms, while the ballroom is frequently used for investitures. Electricity was first installed in the ballroom in 1883 and over the next four years it was extended throughout the palace. Today there are some 40,000 light bulbs in use and since 2005 traditional bulbs have been replaced with LED low-energy bulbs wherever possible.

Of the palace's 775 rooms, there are 19 state rooms, 52 royal and guest bedrooms, 188 staff bedrooms, 92 offices and 78 bathrooms. There are some 1,514 doors and 760 windows in the palace; incidentally all the windows are cleaned every six weeks. Aside from the state, private and staff apartments, the palace has its own chapel, post office, swimming pool, staff cafeteria, doctor's surgery and even a cinema. However, despite rumours to the contrary, the palace does not have its own private Underground station!

The gardens are private and surrounded by high walls. They cover 16 hectares (40 acres) and include a lake, tennis court and helipad. Over 99 per cent of green waste produced in the gardens is recycled on site. They are thought to contain about 30 different species of bird and over 350 species of wild flowers. The setting for the annual royal Garden Parties introduced by Queen Victoria in 1868, the gardens have also hosted a charity tennis competition, pop and classical music concerts and a children's party.

Although Buckingham Palace claims to be the world's largest working palace, there are other bigger contenders such as the Apostolic Palace in the Vatican City, Rome, the Royal Palace of Madrid in Spain and the Istana Nurul Iman Palace – home to the sultans of Brunei – which stands on the northern coast of Borneo. Whether or not Buckingham Palace is the world's largest operational palace, it is nonetheless an instantly recognisable symbol of London, the royal family and Britain as a whole.

## Changing of the guard in focus

The changing of the guard, or guard mounting, is the process during which the new guard relieves the old guard. Dating back to the 17th century, the household troops stand sentry over the reigning sovereign and have been present at Buckingham Palace since 1837. Taking place at 11.30am each morning from May to July and on alternate days through the rest of the year, the ceremony is accompanied by a guards band, which plays a range of music, including themes from films, musicals and even pop songs. Over 2 million people watch the changing of the guard each year. The guard's uniform of black trousers, red jackets and tall bearskin hats has become synonymous with the British royal family and Buckingham Palace.

### 1826
**House to palace**
George IV transforms Buckingham House into a palace. The king employs John Nash and asks Parliament for £450,000 to cover the work.

### 1830
**All change**
George IV dies and William IV takes the throne. John Nash is dismissed for having spent nearly £500,000 on the palace and Edward Blore is appointed to finish the job.

### 1837
**Queen Vic moves in**
Queen Victoria is the first sovereign to take up residence in Buckingham Palace, in July. It is just three weeks after her accession to the throne.

### 1847
**East wing completed**
More space is needed in the palace so an east wing is added to Edward Blore's design. This wing holds the balcony where the royal family appear on special occasions.

# 201,948

## PORTRAIT BY MOST ARTISTS

For three nights in April 2012, an image of the Queen was projected onto Buckingham Palace, made up of 201,948 self-portraits created by British children.

**DID YOU KNOW?** *Although Buckingham Palace is known the world over, it still has a unique postcode: SW1A 1AA*

Buckingham Palace with the Victoria Memorial in front, erected in 1911

### 1911
**Changing of the Guard**
As part of the Victoria Memorial scheme, the world-famous railings and forecourt in which the Changing of the Guard takes place are laid out in front of the palace.

### 1913
**Face-lift**
The soft French stone used on the east front is found to be crumbling, so Sir Aston Webb redesigns the façade and replaces the soft stone with hard Portland stone.

### 1945
**Victory in Europe**
On VE Day (8 May), the palace becomes the focus of celebrations, with the Royal Family appearing on the balcony to the cheers of the crowds on the Mall.

### 1993
**Open house**
Ever since the summer of 1993 the public have had access to Buckingham Palace's state rooms during August and September, when the Queen is not in residence.

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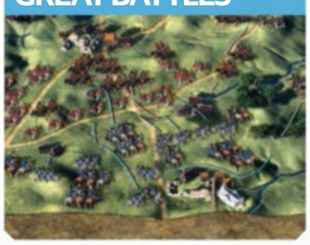

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**1. MOST RELAXING**

**Fort Recovery**
Built on Tortola in the British Virgin Islands, Fort Recovery is now part of a wider beach hotel complex, which has been constructed around it.

**2. MOST HOMELY**

**Aughinish Tower**
This tower in Aughinish in County Clare, Ireland, dates from 1811. In the Eighties it was converted into a private residence.

**3. MOST EDUCATIONAL**

**Carleton Tower**
Located in Saint John, Canada, Carleton Martello Tower is a museum and has been restored to reflect the real layout and conditions of the 19th century.

**DID YOU KNOW?** Some Ancient Chinese candles were made out of fat taken from whales

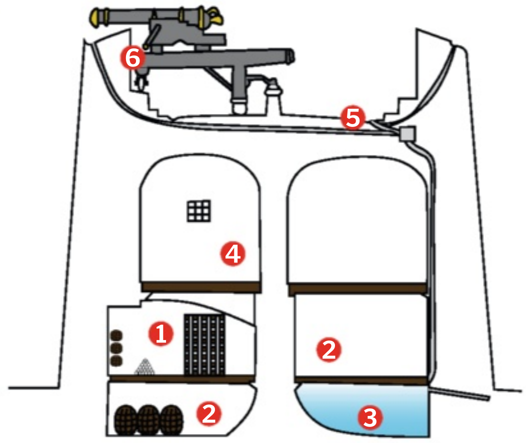
# Mighty Martello towers

## How did these small forts help defend strategic positions around the globe?

Martello tower became synonymous with British territories throughout the 19th century. Large numbers of these small forts were erected at strategic military positions both at home and abroad. Today, Martellos can be found from Canada to Australia – a testament to their sturdiness.

It evolved out of the larger round fortress. These buildings had been designed to withstand cannon fire, with their strong build and squat profile making them hard to incapacitate from distance. The British, wishing to protect territories that could be attacked by water, favoured the Martello as the fortress of choice. It allowed a small group of 24 soldiers and an officer to hold a wide area with the Martello's roof-mounted cannon, while also serving as a lookout and early-warning post.

The Martello became popular in the 19th century, with Britain building hundreds worldwide to oversee its increasingly restless empire. But by the end of the Victorian era, Martellos were rendered obsolete, with rifled artillery weapons making even their thick walls vulnerable. From the 1870s onward, Martello towers largely fell out of use.




### Inside a Martello tower

**Check out the floor plan of this mini fortress now**

**1 Powder store**
Powder and ammunition for the cannon, as well as the troops' armaments, were kept on the ground floor.

**2 Supply rooms**
Two rooms were designated for supplies: one on the ground floor and one in the basement. Food was typically kept in the cool basement and tools on the ground floor.

**3 Water tank and drain**
As Martellos could be under siege by enemy forces for prolonged periods, a water tank and supply was plumbed into the basement.

**4 Quarters**
The tower's garrison of 24 men and one officer lived on the first floor of the tower, which was divided into several smaller rooms. The officer would have his own bedroom.

**5 Roof**
The roof was flat and featured a high parapet, with the roof and first floor acting like an armoured casemate.

**6 Cannon**
In the middle of the roof was a raised gun platform with pivot and cannon. The weapon could rotate in a full circle in order to fire in any direction.

# How did we make candles?

## Shining a light on the manufacturing process behind this valuable source of illumination

Long before the advent of the light bulb, candles were our primary form of artificial light, with the art of candlemaking, or chandlery, both celebrated and profitable for those with the necessary tools and expertise. Indeed, while today candles are made en masse by machines, right up until the early-20th century teams of workers harvested the raw ingredients, prepared them in industrial workshops and moulded them into the finished product. Of course, with the arrival of the electric light bulb, the industry went into decline. Take a closer look at a typical Victorian candlemaking workshop in this annotated illustration.


**1 Rending the fat**
Before modern-day wax varieties were produced candles were made with tallow, which was rendered by melting animal fat.

**2 Storing the tallow**
The melted tallow was put in large vats for easy transport. Metal kettles were used to scoop it up for pouring into moulds.

**3 Preparing the wicks**
Professional makers spun wicks out of strands of cotton. Amateur makers used strands of any material they could acquire.

**4 Dipping the wicks**
Prepared wicks were dipped in tallow repeatedly to build up a base layer and lend the wick some strength.

**5 Pouring the tallow**
Often piston-powered moulds took a wick through a small hole before melted tallow was poured in around it.

**6 Hanging the candles**
Once extracted from the mould, the candle would be cleaned and hung from a rack to harden before being sold.

© Corbis

"When originally completed these sculptures would have been brightly painted and highly detailed"

# Making the Terracotta Army

## Meet the immortal warriors built to defend the Chinese Emperor Qin Shi Huang and find out how they were constructed over 2,200 years ago

The Terracotta Army comprises a huge collection of sculptures found within the mausoleum of the first emperor of China, Qin Shi Huang. Featuring close to 9,000 figures, objects and weapons, the massive earthenware cohort was built to accompany Emperor Qin into the afterlife.

The terracotta army was manufactured by thousands of labourers and craftsmen during Qin's reign around 220-210 BCE. The material used to build the sculptures was harvested from the site of the mausoleum – Mount Li in Shaanxi Province. According to detailed examination of the figures, their heads, arms, legs and torsos were modelled and fired separately, only being assembled afterwards, so many more were probably made but damaged during production.

While today the excavated figures have reverted to their natural orange-red colour due to exposure to the air, when originally completed these sculptures would have been brightly painted and highly detailed – evidence of which can still be found on a few well-preserved specimens. What does remain unchanged is their original layout, with the thousands of statues arranged in accurate military formations, with generals and other important officers identified.

The Terracotta Army is but one feature – albeit the most impressive one to date – of Qin's larger mausoleum and necropolis, with the emperor's tomb and underground palace yet to be excavated. According to famous Chinese historian Sima Qian (circa 145-90 BCE), all manner of treasures are concealed there, but the site is considered sacred so there are no immediate plans to disturb the tomb.

## Beyond the warriors…

### Officials

Qin also needed protection from the trials and tribulations of administration work. Terracotta court officials and counsellors can therefore be found throughout his enormous mausoleum.

### Acrobats

In contrast to the sombre and serious terracotta soldiers, other pits within Qin's mausoleum have revealed acrobats and dancers, each crafted in animated positions and with strong facial expressions.

### Musicians

Music was important in Ancient China, which is represented by the abundance of musicians and instruments. A set of Bianzhong bronze chimes was recently unearthed in very good condition.

### Animals

Emperor Qin Shi Huang was clearly a big fan of animals, as a host of sacred creatures, such as cranes and swans, as well as a full-blown imperial zoo, have been found inside the mausoleum.

## All about Qin

Qin Shi Huang, the legendary first emperor of China, brought the Warring States period to a close in 221 BCE. His reign was typified by military conquest, with campaigns into modern China's southern lands, as well as massive public projects; examples include the unification of state walls into the Great Wall of China and a national road system. Qin ruled unopposed until his death in 210 BCE – an event he reportedly attempted to avoid by undertaking a search for a fabled elixir of immortality.

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"All professional wrestlers belong to a sumo 'stable', where they not only practise but also live"

# Sumo wrestling explained

## What are the origins of this heavyweight martial art and how has it evolved over the centuries?

There are certain pastimes that come to define a country. England has cricket and football. America has baseball and basketball. And Japan has sumo. Dating back some 2,000 years, sumo's roots are generally believed to lie in the country's native Shinto religion where ritual dances were a regular feature of prayers and storytelling, as well as a display of strength in court. It was during the Edo period in the 17th century that it became more like the spectator sport we're familiar with today, though many of its original customs still prevail.

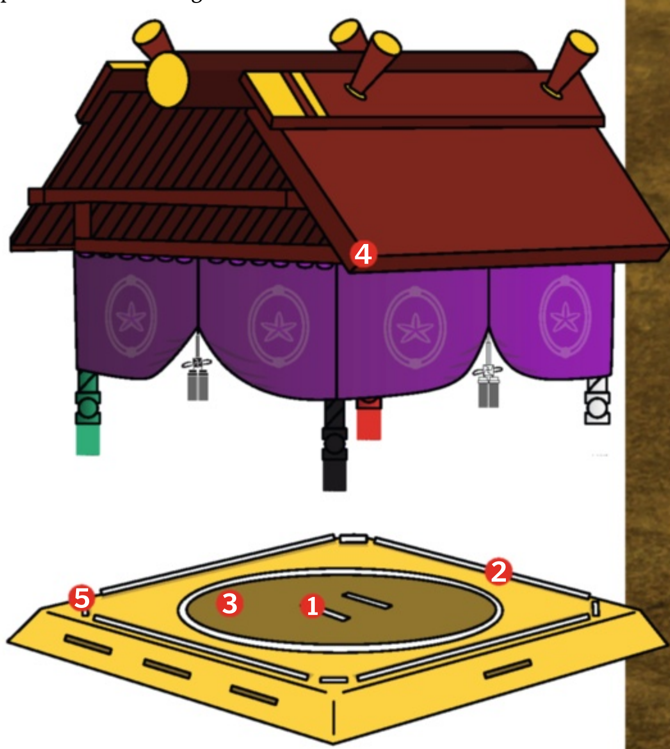
On the face of it, the aim of the game is very simple: either get any part of your opponent (excluding the bottom of their feet) on the ground, or force them entirely out of the ring (called a 'dohyo'). However, in reality this ancient sport is far more complex than it appears on the surface, laden with symbolism and complicated rules. Indeed, over 70 different techniques can be used to win a match, including lifts, throws, trips and even slaps.

Wrestling bouts tend to only last for seconds, or a few minutes at most, with much more time dedicated to the ritualistic practices like feet stomping and purifying the ring with salt beforehand. The fight is overseen by the gyoji, who is essentially the referee, but also five judges; typically the winner is declared by the gyoji, but if a bout is too close to call, the judges can step in and call a conference – these days accompanied by video replay.

All professional wrestlers (known as rikishi) belong to a sumo 'stable', where they not only practise but also live – often from their mid-teens. Everything the wrestlers do, from how much they train to what they eat and when they sleep is carefully monitored by a stable master. It is a strict lifestyle, but one that offers the chance to earn great rewards for those that persevere through the ranks. As Japan's national sport it still commands a certain cache, though younger generations are increasingly enjoying other imported sports, including baseball and football.

### Around the dohyo

**Take a closer look at the ring where sumo wrestlers face off**




**1 Shikirisen**
Two white lines at the centre of the dohyo mark where the wrestlers should stand prior to the bout.

**2 Tawara**
The edge of the ring is bordered with rice-straw bales that stand about 7.6cm (3in) proud of the clay dohyo.

**3 Dohyo**
The circular platform sits on clay blocks and has a diameter of 4.55m (14.9ft). It is covered with a thin layer of sand.

**4 Roof**
The roof is similar to a Shinto shrine's. Azure, black, white and vermilion tassels hang in the corners representing the seasons.

**5 Salt box**
Wrestlers spread salt over the ring and stamp the ground prior to a bout in order to rid the dohyo of evil spirits.

**RECORD BREAKERS**
**SUPER SUMO**

# 319.3kg

## WORLD'S HEAVIEST LIVING ATHLETE

Officially recognised as the ultimate heavyweight in the sporting world, Emmanuel 'Manny' Yarborough, from New Jersey, USA, is over 2m (6.6ft) tall and weighs 319kg (704lb). His nickname is 'Tiny'.

**DID YOU KNOW?** *Professional sumo wrestling is divided into six divisions; the top level, makuuchi, includes the 42 best wrestlers*

Sumo fights are fierce events, but are often over in seconds

© Alamy

# BRAIN DUMP

Because enquiring minds need to know...

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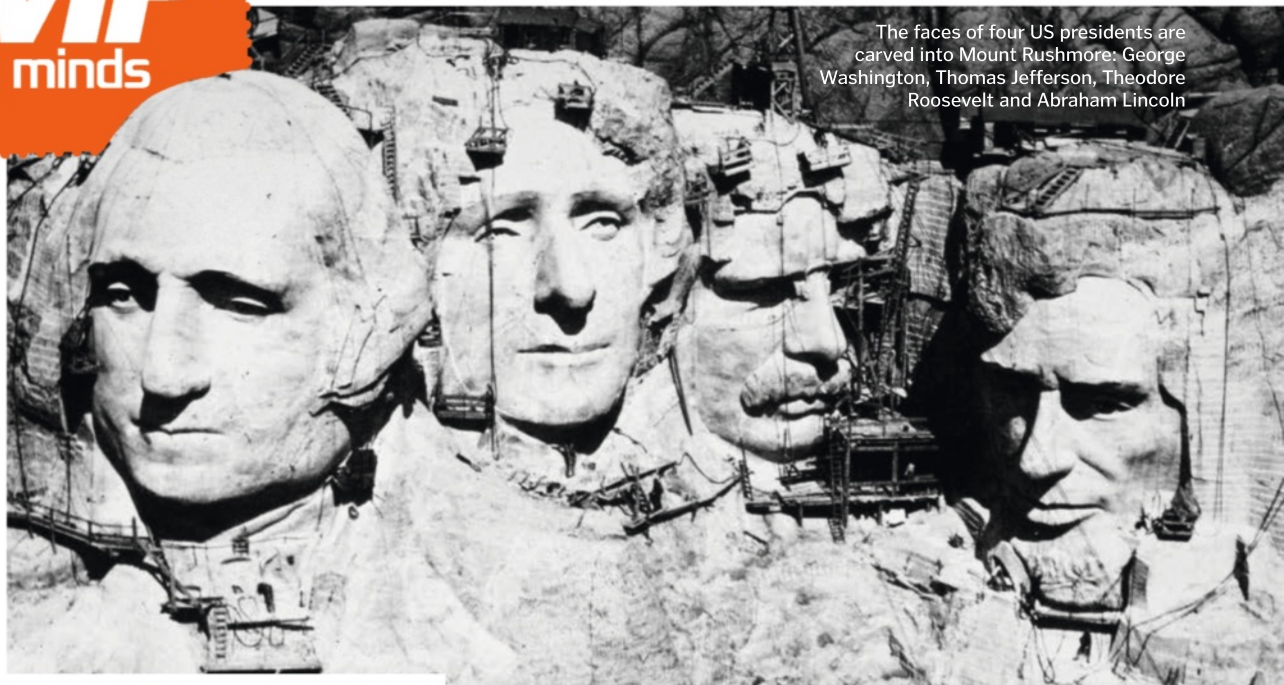


The faces of four US presidents are carved into Mount Rushmore: George Washington, Thomas Jefferson, Theodore Roosevelt and Abraham Lincoln

## MEET THE EXPERTS

Who's answering your questions this month?

**Luis Villazon**

Luis has a degree in zoology and another in real-time computing. He's been writing about science and technology since before the web. His science-fiction novel, *A Jar Of Wasps*, is published by Anarchy Books.

**Giles Sparrow**

Giles studied Astronomy at UCL and Science Communication at Imperial College, before embarking on a career in space writing. His latest book, published by Quercus, is *The Universe: In 100 Key Discoveries*.

**Alexandra Cheung**

Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

**Rik Sargent**

Rik is a science communicator who has a background in physics and public engagement, having worked at the Institute of Physics. Pastimes include experimenting with sound, baking cakes as well as the complex science of brewing coffee.

**Mike Simpson**

Michael has a doctorate in moss as well as teaching awards from the University of Alberta. While not working as a botanist or environmental consultant, he writes, both for magazines and online media.

## How were the Mount Rushmore presidents sculpted out?

**Toni Schulz**

■ The carving of Mount Rushmore's faces started with a bang. Initially, dynamite charges that had been cut down to reduce their power were planted in holes drilled in the mountain at pre-planned positions. This produced a rough outline of the presidents' faces. The finer details were then carved by first drilling a series of shallow holes close together. This so-called 'honeycomb' approach allowed the carvers to more easily chip away the rock. After that, finishing touches were applied using handheld pneumatic hammers and a bumper tool that smoothed out the surface. 700 steps and a tramway got workers and equipment to the top of the mountain, where they were lowered down in leather harnesses suspended on thick steel cables. The carvers were assisted by pointers, who marked where the dynamite charges had to be planted, and 'call boys', who relayed instructions between workers on the rock face and winch operators above. **MS**

## Are seasickness and altitude sickness the same thing?

**Paula**

No, they're not – altitude sickness is a collection of symptoms brought on when you're suddenly exposed to a high-altitude environment with lower air pressure so less oxygen enters our body. The symptoms can include a headache, fatigue, dizziness and nausea.

Seasickness, on the other hand, is a more general feeling of nausea that's thought to be caused when your brain and senses get 'mixed signals' about a moving environment – for instance, when your eyes tell you that your immediate surroundings (such as a ship's cabin) are still as a rock, while your sense of balance (and your stomach!) tell you something quite different. This is the reason why closing your eyes or taking a turn out on deck will often help, as it reconciles the two opposing sensations. **GS**

# COOL FACTS

## Ancient Egyptians built lighthouses as well as pyramids

Lighthouses originated as hill fires warning sailors of nearby rocks. One of the earliest known lighthouse buildings is the famous Pharos of Alexandria, which was built in Egypt around 280 BCE.

## Why do boomerangs come back?

**Daniel Jessop**

■ Gyroscopic and aerodynamic forces are responsible for a boomerang faithfully returning. The two arms on a boomerang are shaped a bit like wings on a plane – slightly curved on top and flat underneath. This generates lift as the two arms spin, keeping it in the air, similar to how a helicopter stays aloft. As a boomerang spins, one arm at any given moment actually moves faster than the other – with respect to the air – as the boomerang continues in its direction of motion. This creates a greater lift force on the arm that spins in the direction of the boomerang's path, resulting in unbalanced forces that gradually change the boomerang's direction. Throwing a boomerang horizontally would cause it to curve upwards, where it would fall back down and not return to its starting point. A boomerang should be thrown at an angle between 20-45 degrees right of an imaginary vertical line, for it to have a chance of returning. **RS**

## Where do the biggest dust storms occur?

**Sandy Watkins**

■ Mars is home to the largest and most powerful dust storms ever recorded. Martian dust storms have been known to engulf the entire planet in a haze for months at a time, making it difficult to single out one as being the biggest. Dust and sandstorms on Mars and Earth happen due to temperature differences in the atmosphere. Hot air moves to colder air, and this moving air can pick up tiny debris in arid landscapes. It is not known exactly why storms on Mars can spread so far, however the fact it is such a dusty world probably has something to do with it! **RS**

## Could the internet ever run out of space?

**Lacey Cook**

■ No. The internet isn't a thing in and of itself, it's a concept. All the computers in the world that are connected to the internet are themselves part of it. As the individual storage of each web server gets upgraded, so the capacity of the Internet gradually increases. There are always limits imposed by current technology – to the total number of unique internet addresses, for example, or the number of simultaneous connections that each server will accept. However, new protocols and hardware are continually developed to extend these limits, so the internet will inevitably continue to grow for as long as we need it to. **LV**

## What are galactic clusters?

**Ian Molinder**

■ A galaxy cluster is any group of galaxies whose gravity is enough to overcome the general expansion of the universe and hold it together. About half of all galaxies are found in clusters of one sort or another. The least impressive clusters, known as galaxy groups, typically contain a handful of large systems surrounded by a few dozen smaller dwarf galaxies – our Milky Way galaxy, for example, is one of three large spirals in the so-called Local Group. Dense clusters, however, may contain up to a couple of thousand galaxies including dozens of large spirals and elliptical (ball-shaped) galaxies. Curiously, the size of clusters does not vary all that much – they are always around one to ten megaparsecs (or 3-33 million light years) across. **GS**

Why are rip tides so dangerous? Find out on page 82

Comets rarely survive the entry into Earth's atmosphere and usually explode before hitting the ground

## Has a comet ever hit our planet?

**Abbie Pitman**

Yes – on a cosmic timescale, comets hit the Earth frequently, but because they're largely made of ice rather than solid rock, they tend not to leave obvious craters. A small comet is more likely than an asteroid to break up as it plunges into Earth's atmosphere and heats up, often resulting in an explosion called an airburst that can devastate large areas of the landscape but doesn't leave a crater. Perhaps the most famous such event happened over the Russian region of Tunguska in 1908, when an exploding comet flattened some 2,000 square kilometres (770 square miles) of Siberian forest. A comet would have to be pretty big in order to hit the ground intact. **GS**

## COOL FACTS

### The oldest recorded bird today is an octogenarian

In the wild, albatrosses can live for 50-60 years, but the oldest bird currently in captivity is Cookie the cockatoo of Brookfield Zoo, Chicago. He was hatched in June 1933, making him over 80 years old.

## What are rip tides?

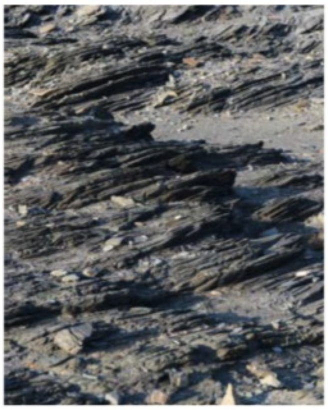
**Ashley Weeks**

The term 'rip tide' is a misnomer as it refers to a narrow directional flow of water that has nothing to do with the gravitational attraction of the Sun and Moon; it is more of a 'rip current'. When waves are pushed against the shore by high winds the water can respond to the resistance that solid ground generates by travelling parallel to the coastline. If some of it finds an underwater trench or a gap in a sand bar, it can be channelled rapidly back out to sea, pushed on by the force of incoming waves. As this all occurs beneath the surface, it can catch people unaware and so they often get swept out too. **MS**

## Why can't all plastic be recycled?

**Beth Chandler**

Most plastic can be recycled; the issue is that the cost for recycling plants to sort through so many different types of plastic exceeds the cost the recycled material can be sold for. There are many different types of plastic in use for consumer products, including PET, PP, HDPE and PVC, which can all be melted and reused. However, they cannot be mixed, forcing recycling plants to only recycle the most commonly used plastics, such as HDPE (plastic milk bottles) and PET (carbonated drinks bottles). Recycling would be much easier if most things were made from only one or two types of plastic. **RS**



## Where does slate come from?

**Rachel Carr**

Slate is a metamorphic rock. The slate in North Wales began as mud that settled at the bottom of the sea some 500 million years ago. As new layers settled on top, the lower ones eventually get compressed to form shale. Over millions of years the tectonic plates shifted and wrinkled to form the Welsh mountains and the shale became heated and compressed. This caused the minerals in the shale to partially melt and reform as thin sheets of mica and quartz. Because of the particular way the crystals grow, the layers of slate are at right angles to the original shale layers. **LV**

## Why do we develop gout?

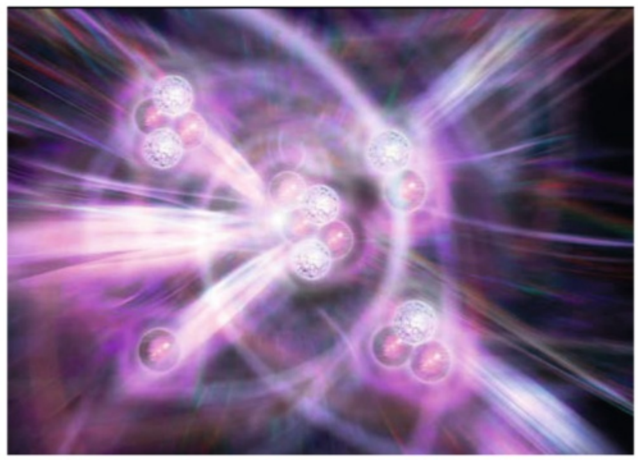
**Imran Khouri**

Excessive levels of uric acid in the blood cause gout. We produce uric acid as a waste product from digesting protein. In a healthy person, uric acid is removed by the kidneys and excreted as a dilute solution (urine). But if your kidney function is impaired, the concentration rises to the point where it precipitates as monosodium urate crystals. These normally form in the joints of your toes, because your feet are cooler and cold temperatures reduce the solubility of uric acid. Gout is partly genetic, but exacerbated by excessive drinking – particularly beer – and not enough exercise. **LV**

## How do atoms decay?

**Rhys**

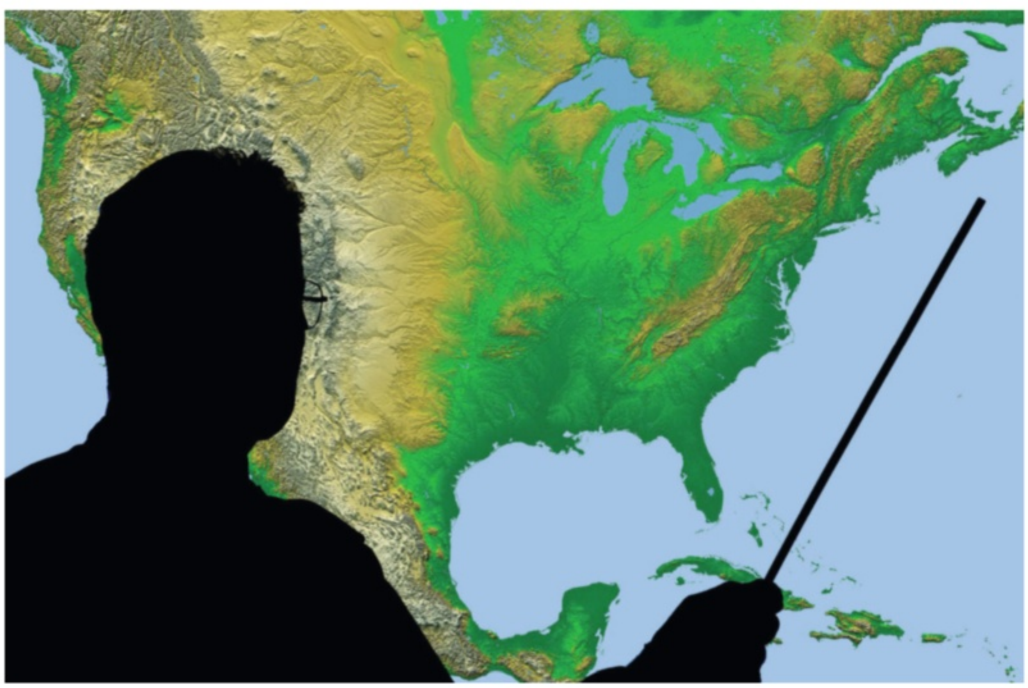
When a radioactive atom decays, it loses energy by emitting particles or radiation. This process changes the composition of the nucleus, often transforming it into a new element. A carbon-14 atom has six protons and eight neutrons. When it undergoes beta decay, one of its neutrons splits into a proton, an antineutrino and an electron. The electron (also known in this case as a beta particle) and the antineutrino are ejected from the nucleus. The nucleus now has seven protons and seven neutrons – making it a nitrogen-14 atom. **AC**



# When did we start forecasting the weather?

**Matt Kavanagh**

People have been trying to forecast weather since before the dawn of recorded history. For early civilisations, it wasn't just out of curiosity either – their direct dependence on agriculture made the weather a matter of life and death. The earliest forecasts we know about, from Ancient Babylon during the seventh century BCE, were rooted in astrology, but the Ancient Greeks and others developed sophisticated 'weather lore' based on their observations of patterns in the natural world. Some of their observations were genuinely useful, others not so much, but this folklore still lingers today, in sayings such as 'Red sky at night, shepherd's delight'. The first instruments for scientifically measuring properties such as atmospheric moisture and pressure were invented during the Renaissance, but the arrival of the electric telegraph in the mid-19th century permitted rapid collection of data from large numbers of remote weather stations – the key to modern weather forecasting. **GS**



**How does snake-charming work?** Find out on page 85

## COOL FACTS

### The biggest planet has the shortest day

Jupiter spins on its axis in just 9 hours 55 minutes and 30 seconds, which means that in the gas giant's terms there are over 10,400 days in each Jovian year.

### The original ice cream was Chinese

The first 'ice cream' was eaten in China around 200 BCE and consisted of a milk and rice mixture packed into snow. There are some claims that the Italian explorer Marco Polo brought back recipes of ice cream to Italy from China.

### We made our first element 77 years ago

The first artificial element was technetium, a radioactive, silvery metal. Carlo Perrier and Emilio Segrè created it in 1937 by bombarding molybdenum atoms with deuterium nuclei inside a particle accelerator.

## How are old paintings restored?

**Douglas Clayton**

Reversing the effects of ageing and damage on a painting is a delicate process that uses a variety of techniques. First, a cleaning solution is applied to remove dirt and deposits. Then the restorer identifies previous retouches, shown up under ultraviolet or infrared light, before carefully stripping away discoloured varnish and retouches. Any damage to the canvas or support structure is repaired. Mixed with a binder to form a putty, pigments are applied to areas where paint has been lost. These retouches may be removed with solvents that will not damage the original painting, meaning any changes can be reversed. **AC**

## Why are bees making blue honey?

**Thorsten Gerber**

When bees in the French town of Ribeauville started producing blue and green honey in 2012, dyes from an M&M waste plant were to blame. While bees produce different shades of honey depending on which flowers they collect nectar from, blue honey was previously unheard of. Beekeepers discovered their bees had switched food sources, shunning local flowers in favour of brightly coloured, sugary M&M shell fragments being processed at a neighbouring biogas plant. Bees then transformed these sugars – along with the dyes – into honey. The waste-processing plant has since tidied away any uncovered waste containers, spelling the end of the blue honey. **AC**

## What were Stanhope viewers?

**Robert Powers**

They were a modification of the Stanhope lens invented in the 18th century by Charles, the Third Earl Stanhope. It was rod-shaped and included two curved lenses. In the mid-19th century René Dagron adapted it for purposes of microphotography. Dagron added a convex magnifying lens to one end of the cylinder and swapped the curved lens at the other end for a flat one. He then sold it as a novelty item for viewing tiny photos within jewellery and other souvenirs, which could otherwise be seen only through a microscope. **GS**

Stanhopes were also fitted into violin bows with images of famous composers

Chemical engineers put their knowledge to use in many aspects of technology and science

# What do chemical engineers do?

**Chloe Marshall**

Chemical engineers design the industrial processes that transform raw materials into the products we use every day. They find the most cost-effective, safe and environmentally friendly ways of producing anything from pharmaceutical drugs to plastics. Chemical engineers usually fall into one of two broad categories: process engineers, who design, construct and operate plants, and product engineers, concerned with developing new materials and substances. They apply their knowledge to alter the physical and chemical properties of different substances and materials. Chemical engineers are in demand across a wide range of sectors and their roles vary accordingly. A chemical engineer employed in the food industry might focus on applying heat transfer and fluid flow principles to the manufacture of foods. While in the energy sector, the job could involve developing fuels from renewable sources or improving the safety of nuclear power stations. **AC**

## Do mood rings work?

**Shelley Reeves**

Mood rings change colour in response to changes in skin temperature. Proponents claim this can happen when shifts in emotional state cause blood vessels to carry blood closer to or further away from the skin's surface. These temperature changes are conducted through the base of the ring to liquid crystals inside and stimulate the crystals to change shape. The modified crystals might reflect different wavelengths of light, causing the ring to change colour. Although mood rings can be said to work in this limited sense, they might also respond to other causes of fluctuations in skin temperature, such as poor blood circulation. **MS**

## How do sunglasses protect our eyes?

**Aaran Donaldson**

Lenses in sunglasses are tinted to filter out light of certain wavelengths, reducing the overall intensity of light hitting your eyes, while minimising glare – reflected ambient light that obscures your vision on a sunny day. Grey, green, brown or red are the most effective at minimising colour distortion the most – important for seeing clearly, especially while driving. Lenses are made from glass or plastic; both are materials that block parts of the UV light spectrum, while allowing visible light through. Therefore, just wearing normal glasses already offers some protection from potentially harmful UV rays. **RS**

## Is it really possible to charm snakes?

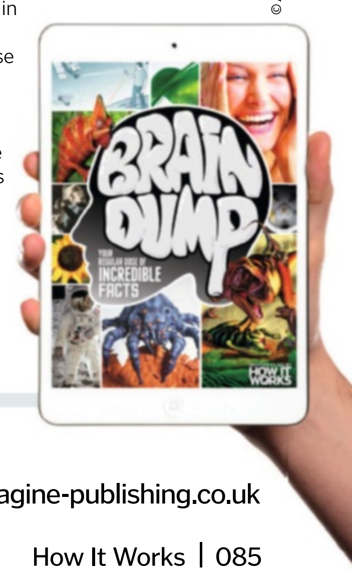
**Jason W**

It's really a street theatre trick. Snakes don't have outer ears and can only sense sounds loud enough to vibrate their skeleton. Although it appears to be dancing in time to the music from the snake charmer's pipe, or *pungi*, it is actually tracking the movements of the pipe itself, as a threat.

Cobras can't reach farther than a third of their body length when they lunge so charmers sit comfortably out of range. Often they will remove the snake's fangs. The fangs regrow in a few days, so this procedure has to be repeated. **LV**

## New Brain Dump is here!

The latest edition of **How It Works**' digital-only sister magazine **Brain Dump** is now available, packed with bite-sized facts from the fields of science, tech, space, transport and more. In issue 10 you'll find the answers to some of your most burning questions, including how to shoot a basketball, how Wi-Fi really works and whether or not astronauts can burp in space. **Brain Dump** is the perfect companion for those always on the move as you can read it on any of your smart devices, including phones and tablets. For the answers to those questions and more, download the new issue from iTunes or Google Play. You can put forward your quandaries at **www.facebook.com/BraindumpMag** or Twitter – @BrainDumpMag.

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# Travel gear

## Want to escape the winter blues? Before heading for the airport, don't forget to pack these useful gadgets…

**Checklist**
- ✔ Ride-on luggage
- ✔ Socket adaptor
- ✔ Insect-bite soother
- ✔ Power pack
- ✔ First aid kit
- ✔ Charging cable
- ✔ Portable speaker
- ✔ Light-field camera

There was a time when travelling meant loading up your saddlebags and cart, then riding your horse to the next town. Things have changed just a little since then and the last decade has given rise to the added complication of which portable electronic devices to take. Today, what to pack your gear in can be as complicated a decision as what to pack. Luckily, there are some incredibly elegant solutions to some distinctly first-world problems of the 21st-century voyager, as we reveal here.

Most of Lytro's functions, including refocusing, are incorporated onto its tiny touchscreen.

With the Lytro camera you can take your shots and then refocus them later

### 1 Luggage scooter

**Micro 3in1 Luggage Scooter**
£249.95/$299.99
**www.micro-scooters.co.uk**

We still love to ride the back of a trolley in the supermarket, so an airport trolley-cum-kickboard is a dream hybrid for us. Made to airport hand-luggage specifications, the Micro 3in1 has a hard-shell body with a telescopic handlebar and can support up to 100kg (220lb) on the kickboard. It's rugged and you can even steer around corners, with a bit of practice. It's fairly pricey for a piece of hand luggage but, practicalities of a trolley aside, jet-setters would be missing out on far too much fun not to buy this scooter.

**Verdict:**

### 2 All-in-one charger

**QDOS PowerMax Dual**
£29.99/$N/A
**qdossound.com**

Packing for a holiday can mean carrying an electrical store's worth of wires and cables to charge and transfer between all your devices. So at least you can kill two birds with one stone with this dual-purpose charging cable. At one end is a standard USB plug and at the other, both a microUSB and a Lightning Connector for Apple gadgets. You can't charge or sync two devices at once, however, and even if you do factor in what you'd pay for an Apple-branded Lightning Connector, £30 is quite a big outlay for a charging cable.

**Verdict:**

### 3 Party on the go

**QDOS Q-BOPZ**
£29.99/$N/A
**qdossound.com**

This Bluetooth speaker packs a decent wallop of punchy sound into its pocket-sized chassis. Designed for use with smartphones and similar portable gadgets, it has an ample range of up to 10m (33ft), it is splash resistant and has more than enough battery life between charges – up to seven hours, depending on the volume. It charges via USB (the cable is included) and also features a super-strong suction pad for sticking onto most surfaces. This is a solid audio solution for a traveller who can't be without their music.

**Verdict:**

### 4 Adjustable focus

**Lytro camera**
£399.95/$399
**www.johnlewis.com | store.lytro.com**

The Lytro is one of the more innovative gadgets here: a cuboid camera that takes what the manufacturer calls 'living images'. By capturing the entire light field rather than a two-dimensional snap, you can refocus on any subject in the frame *after* shooting the photo. In practice, that takes a little bit of experimentation before you get used to the kind of shot that best takes advantage of this technology. Though this feature is very cool, it is worth considering that the same money could also buy you a half-decent DSLR.

**Verdict:**


# EXTRAS

The paper and virtual resources for all your travelling needs...

**BOOK**

## Best Ever Travel Tips

**Price:** £4.99/$9.99
**Get it at: www.lonelyplanet.com**
Lonely Planet is one of the greatest authorities when it comes to travel advice. This bumper book of top tips from the experts will help you with everything from saving money to keeping safe – and it comes at a bargain price too. A worthy read.

**APP**

## Google Translate

**Price:** Free
**Get it from:** Google Play/iTunes
With translation between 64 different languages and including audio, Google's Translate app can be a pretty handy partner abroad on your phone or tablet – short of having a talented multilingual translator at your side, of course.

**WEBSITE**

## www.gogobot.com

'Plan the perfect trip' is this site's headline, and the simple premise of entering your destination, creating an itinerary and reading tips from fellow explorers who have 'been there, done that' makes it a top tool.

## 5 Universal adaptor

**Worldwide Travel Adaptor**
**£17.99/$N/A**
**www.ryman.co.uk**
Argentina, the Bahamas, Japan, Australia, Turkey, Malaysia… you name the country, it's more than likely that this one-size-fits-all adaptor will work there. Its compact body houses four different plug types compatible with countries in Europe, the US, Australia and China. Just slide the lever along its length to reveal the fitting you require and stick the appliance's plug into the other side. It's important to note that it doesn't transform voltages, so you have to be careful when using UK devices in US sockets, for example.
**Verdict:**

## 6 Pocket medic

**Karrimor Pocket First Aid Kit**
**£11.99/$TBC**
**store.karrimor.com**
Looking at the items this contains, it's not exactly the comprehensive kit a careful holidaymaker might take with them. Sure, there are ten washproof plasters, two hydrocolloid blister plasters, alcohol wipes, an insect repellant wipe, a medium dressing and an emergency foil blanket, but short of a mosquito net, it feels more like a single-use emergency kit for a weekend camping trip than a long vacation. You're paying as much for the actual kit bag as what it includes. However if you're only going away for a short trip, this should do the trick.
**Verdict:**

## 7 Portable power

**Kit Premium Power Bank**
**£49.99/$N/A**
**www.robertdyas.co.uk**
Sometimes you're not near a convenient power socket to charge up your smartphone or tablet. You might be halfway up a mountain when your mobile flashes up a battery warning and you're minutes away from being cut off from civilisation. This might not sound like such a bad situation, until you actually need the device in question. With a dual output, 12,000mAh capacity, the Power Bank can top up Apple or Android devices fast, for up to 17 hours. Bigger brands have this market cornered, but this portable battery pack is about as compact as they come.
**Verdict:**

## 8 No more itching

**Go Travel Bite Relief**
**£8.99/$12.95**
**www.robertdyas.co.uk**
Traditional relief from mosquito bites has involved a cocktail of chemical applications – from wipes to creams and gels. So in many ways this tiny, T-shaped device is a breath of fresh air. It uses a piezoelectric quartz crystal to generate a high-voltage, low-density current that, when the nub is applied to the bite and the trigger squeezed, provides rapid relief from the itching. It gives you a little bit of a shock (we are dealing with electricity here, after all) but, to our surprise, it works rather effectively and quickly too.
**Verdict:**

# GROUP TEST

Putting products through their paces

# Network audio players

## Sync all your audio needs with a home network using these cutting-edge machines built to amp up your media

**AirPlay included**
Apple's AirPlay is the patented wireless streaming standard that allows Apple products to stream media to compatible devices. This feature was missing from the RCD-N8's predecessor but Denon has rectified this in the new CEOL.

**Super-crisp audio**
The Sneaky's DAC supports a high sampling rate. The actual difference between 192KHz and lower-quality audio is for the academics to argue about. Regardless, the audio reproduced by Sneaky's DAC is exceptionally detailed.

**Analogue to digital**
Converting from old vinyl records to digital music is handled by a DAC chip. This 'samples' the music in blocks, effectively turning peaks and troughs in the signal into a series of zeros and ones.

4

**USB-B**
By using the USB-B connection of the NA-11S1, music can completely bypass the sound card and mixer on your PC for unmodified audio.

### 1 Denon CEOL RCD-N8

**Price:** £399.95/$TBA
**Get it from: www.denon.co.uk**
The new lightweight, pearl-finished CEOL box is about as plug-and-play as they come. In only a few steps, you've connected to either your wired or wireless network, ready to stream music from your home network, via internet radio or online services. The CEOL supports a wide range of music formats and packs 65W of power into its amp for a well-rounded punch of sound when paired with a quality pair of speakers. It's fully furnished with a suite of audio input options, including CD, but stops at Bluetooth – a shame given how complete this package is otherwise. Speakers are extra, of course, though the two that are paired with this system don't do it justice.
**Verdict:**

### 2 Linn Sneaky DSM

**Price:** £1,750/$N/A
**Get it from: www.linn.co.uk**
Scottish audio specialist Linn offers a comprehensive solution in its aptly named 'Sneaky' DSM. The software suite was also developed in-house and it even has its own online music store – **www.linnrecords.com** – where you can buy the high bit-rate songs the Sneaky is capable of pumping out. It's an intriguing-looking thing, but the £1,750 question is: how does it sound? Setup is quite easy – just follow the wizard and you can't go wrong. The Sneaky plugs in to your router and after setting up, a media server will allow you to stream audio from a number of sources – and there's no two ways about it, it sounds incredible. The Sneaky's main drawback is that it has no wireless input as Linn feels Wi-Fi doesn't support high-quality audio.
**Verdict:**

### 3 Cocktail Audio X30

**Price:** from £879/$N/A
**Get it from: www.cocktailaudio.co.uk**
Cocktail's 'Big Brother' to its older X10 strikes the balance between price and features of this **HIW** lineup. This hi-tech piece of kit is both an HD music server and network streamer, with integrated CD-ripping and a power amplifier with 50W per channel – more or less all your music-playing needs contained in a single box.

To compete at this price level, the X30 supports high-resolution, 24-bit music files and gapless playback. Its capacity as music server is its standout feature though. It supports hard-disk drives up to 4TB or 500GB of solid-state drive, allowing you to record audio from older media – vinyl or cassette, for example, which means you can archive your music. It costs more than your average streamer but for the quality, ease of use and features, the X30 offers the most value for money in our opinion.
**Verdict:**

### 4 Marantz NA-11S1

**Price:** £3,499/$3,499
**Get it from: www.marantz.com**
Leading the pack on both quality and price here is one of the market leaders, Marantz, with this high-end offering. Finished in classic brushed aluminium, it features support for a huge range of audio formats, streaming from Spotify, AirPlay and several other online services, plus all the audio inputs and outputs you could possibly want. So what does over £3,000 of network music streamer get you over something a third of the cost – or even less?

For starters, it's incredibly robust, both in terms of what the NA-11S1 can do and how solidly it's been manufactured. One of the major factors in the price of a piece of audio technology like this is the high quality of the digital-to-analogue converter (DAC), but the complete sound it delivers is where you'll hear your money hard at work. It's beyond the budget of pretty much anyone other than a committed audiophile, but their music system will be the envy of the street.
**Verdict:**

## ON THE HORIZON

Four other cool gadgets we're keen to get our hands on...

### SteelSeries Stratus

With the increasing power of mobile devices and trend towards gaming on smartphones and tablets, it was only a matter of time before someone brought out a controller compatible with Apple's portable range. Bluetooth-powered and with ten hours of juice, SteelSeries Stratus could be a godsend for Apple gamers.

### Google Glass prescription

Apparently, the much-hyped augmented reality specs are being made available on prescription. It will come to an optician near you sometime this year.

### Sony Ultra Short Throw Projector

Short-throw projectors are the ultimate alternative to a giant flatscreen TV or conventional projector. It shoots the image directly up against the wall rather than across the room. Sony's version is a monster that projects a 4K image at up to 373cm (147in)! It will set you back around £25,000 ($40,000) though.

### ChefJet

The days of a *Star Trek*-style replicator can't be too far away now, what with the launch of ChefJet, a 3D printer that produces edible items. At the moment, this device can print decorations in chocolate, vanilla, mint and other flavours for the cake and pastry industry.

© SteelSeries; 3D Systems; Google; Sony

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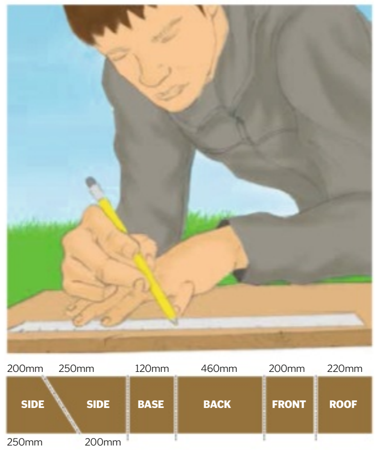
# Build a nest box

Create a perfect home to attract feathered friends to your garden this spring

### 1 Pick the design

To kick off, you have to decide what kind of nest box you want to build. Different layouts will appeal to different birds, so you need to consider which guests you want to host. Robins prefer open-front boxes, swallows like slot boxes with a postbox-like opening, while the traditional hole-fronted box will vary in size between species. For example, the hole needs to be about 2.5cm (1in) across for blue tits and 4.5cm (1.8in) for starlings.




### 2 Tools & preparation

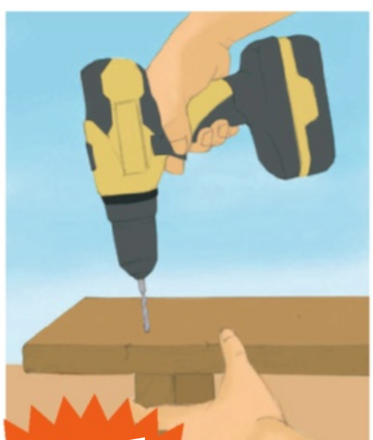
Gather your tools for this project, including a saw, hammer, drill, pencil and ruler. The box is made from a single plank of rough-cut timber 150cm (59in) long, 15cm (5.9in) wide and 1.5cm (0.6in) thick. Other than that, a basic hinge and some nails are all you need. Start by marking out the lines and write the name of each panel, eg 'back', on the wood; these notes will be on the inside so they won't show by the end.

### 3 Get cutting

Use the lines you just drew on the plank as a guide to carefully saw it into six panels: two sides, base, back, front and roof. The front/roof sections need to be cut at a 45-degree angle. The front panel will also vary depending on the nest box design. If using a hole, make sure it is positioned at least 12cm (4.7in) above the base, so the chicks can't stumble out. Also drill a few small holes in the base for ventilation and drainage.

### 4 Assembly time

Attach one side onto the back wall, then the base and the second side. Next nail in the front panel to the three existing walls. The roof requires a little more work as it needs to be fixed with a brass or plastic hinge (neither of these materials rust) so you can clean the box in autumn. It's advised not to treat the wood with preservative in case the chemicals harm the residents, though certain ones are safe for animals (eg Sadolin).



### 5 Mount the box

The placement depends on the bird you're hoping to attract – house sparrows and swallows like to live in the eaves of the roof, while a tree or wall will suffice for most so long as it's at least 2m (6.6ft) off the ground and in a quiet spot. You can either use nails to attach the box directly to the tree, or secure it around a tree trunk or branch with rope or wire; the latter makes removal easier for cleaning and maintaining the nest box.

### In summary…

Building your own nest box is amazingly simple and, made from a single length of wood, extremely economical too. It's important to use rough timber rather than smooth because the juvenile birds use the coarse surface to help them clamber out when ready to fledge. Try to angle the box so it's facing somewhere between northeast to southeast in order to avoid the most intense sunlight and the heaviest rain.

NEXT ISSUE
- Service your bike
- Dye Easter eggs

**Disclaimer:** Neither Imagine Publishing nor its employees can accept liability for any adverse effects experienced when carrying out these projects. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

# Prepare a fish

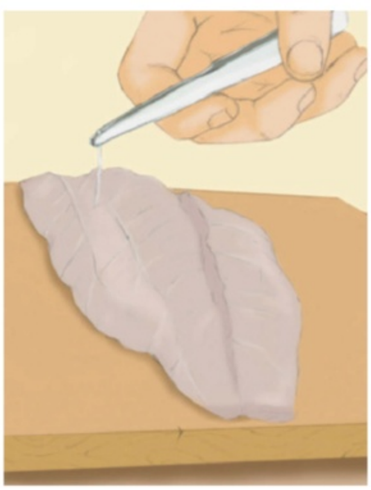
Fresh fish don't always come ready to cook, so filleting is a valuable culinary skill to master

### 1 Remove the scales

The fishmonger will usually do this for you, but if you've caught your own fish this will have to be your first job, otherwise the knife will likely slip when filleting. Use the blunt edge of a knife to slowly scrape off the scales, working from tail to head. Take your time to keep mess to a minimum. When you're done, rinse the fish under cold water and dry gently with a paper towel. Some people like to gut the fish at this stage, but it's best to do this after filleting.

### 2 Cut the fillet

Lay the fish on a board with its back toward you and make a cut just behind the head fin. Continuing backward from this incision, slide the blade along the spine all the way to the tail. Try to keep the movement as fluid as possible rather than sawing away. When you peel the fillet back on some fish (eg sea bass) you may have to deal with the ribs as well; just run the knife over the spine with a bit more force in order to break through these.



### 3 Tidy up

At this stage, you can trim the edges to neaten up the fillet. If you want to remove the skin as well, just make a small cut to free it at the tail end – about 2.5cm (1in) in. Now you can press the tab of skin firmly down and, holding the blade at a slight angle, extend the cut. Once halfway through, hold the knife still and wriggle the skin from side to side, while pulling backwards. Using this technique the skin should come away fairly easily and in one piece.

**In summary...**

The secret to cutting up a fish is a good knife – preferably a specialised filleting knife with a thin and flexible blade. You can keep it sharp by regularly using a steel. Other handy tools are scissors for snipping off the fins and a pair of tweezers for picking out those pesky bones.

# QUICK QUIZ

Test your well-fed mind with ten questions based on this month's content and win a model of the Severn-class RNLI lifeboat!


Answer the questions below and then enter online at **www.howitworksdaily.com**

1. What percentage of our bodies is made up of carbon?
2. In which year did Mariner 5 perform a flyby of Venus?
3. Our bone marrow comes in two varieties: red and what other colour?
4. At what temperature are seeds kept at the Svalbard seed vault (in Celsius)?
5. How many seconds into his jump from 39km up did Felix Baumgartner hit peak velocity?
6. What's the biggest length that piranhas can grow to (in centimetres)?
7. When was the RNLI sea rescue organisation set up?
8. What stretchy material are balloons made of?
9. How many state rooms does Buckingham Palace (pictured) have?
10. What is the name of the instrument traditionally played by a snake charmer?

**ISSUE 56 ANSWERS**

**1.** 2.9bn **2.** 1908 **3.** 57 **4.** 1,600m **5.** Muon **6.** 6,480 tons **7.** 40km/h **8.** 10 days **9.** China **10.** John

# INBOX
Speak your mind...

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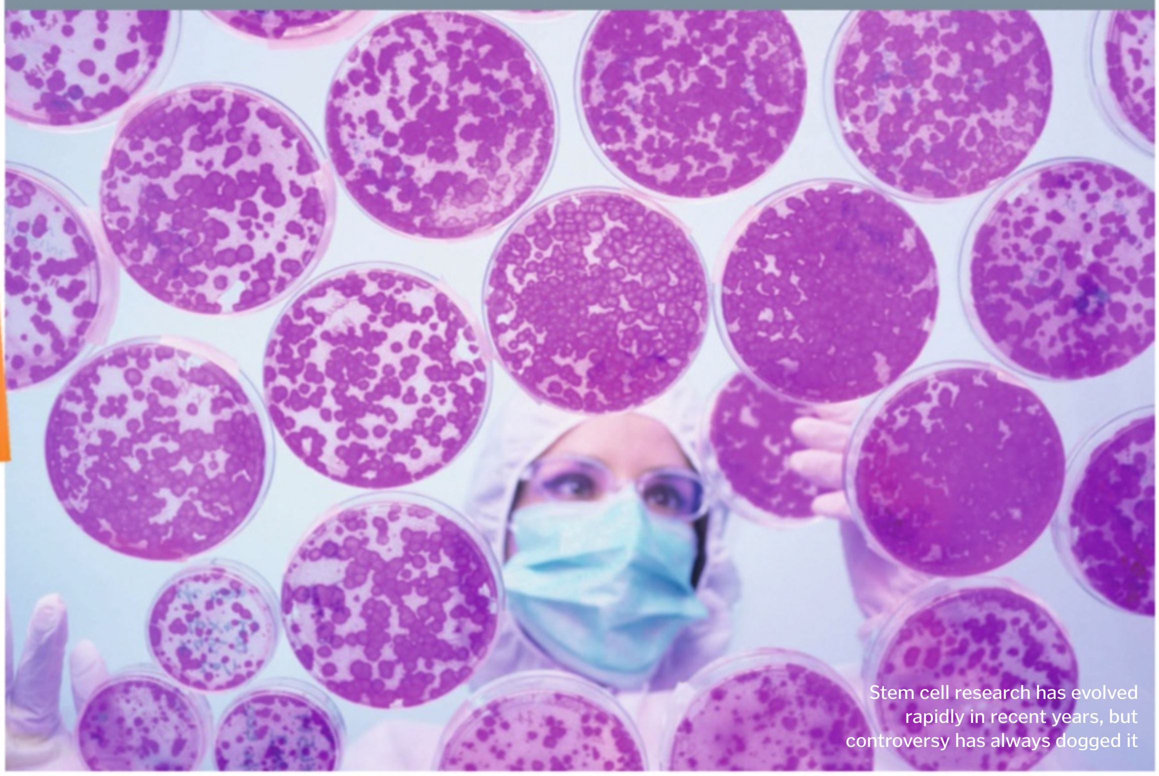
**AMAZING PRIZE FOR NEXT ISSUE'S LETTER OF THE MONTH!**


### DISCOVER PHYSICS' BIGGEST MILESTONES
Next issue's Letter of the Month will win a copy of *Physics: An Illustrated History Of The Foundations Of Science*, which picks out 100 of the biggest breakthroughs of all time and also includes a foldout timeline.

**Letter of the Month**

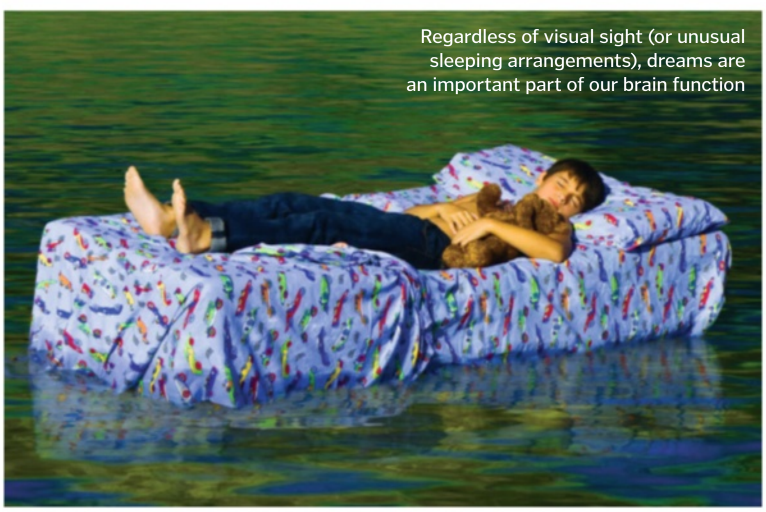
## Stem cells up for debate
Dear **HIW**,
Stem cells have proven to have many medical advantages. One of the main issues with stem cells is that generally when they are harvested it results in the destruction of an embryo, which many believe constitutes the destruction of a human life. However scientists have been able to convert adult cells into stem cells that are the equivalent of embryonic cells. There is no need to use embryonic stem cells at all – it's just cheap and convenient. Some may argue that embryos do not constitute human life, therefore using converted adult cells is a waste of time and money. However, as the issue of when life starts is such a grey area, with evidence supporting and invalidating a whole range of different opinions, it seems 'better safe then sorry' is highly applicable. I personally believe embryonic stem cells should not be used because it is impossible to definitively know that a human life is not being destroyed, but I am all for the use of converted adult stem cells.
**Kate Wattchow, via Facebook**

**Thanks for sharing your thoughts on this thorny issue, Kate, which continues to cause a lot of controversy in the science world. Recently, stem cells sourced from patients' skin were converted into pulsating heart muscle in the lab, and every year, we are making more and more of these mind-boggling breakthroughs that once seemed inconceivable. But while our abilities get ever more advanced, we mustn't forget that with great power comes great responsibility. One thing's for sure, this debate promises to run for a long time yet.**


Stem cell research has evolved rapidly in recent years, but controversy has always dogged it

## Dream on...
Dear How It Works,
Thank you very much for your amazing magazine! The content found in each edition is fantastic and very informative. I have always wondered what would happen to the dreams of a person who was born blind (would they even have dreams?). To add to this question, if a person went from colour vision to being colour-blind, would their dreams change or remain the same? I would greatly appreciate if you could answer these questions for me!
Sincerely,
**Rishi Chandrakumar**

**We're glad to hear you're enjoying the magazine, Rishi. Dreams are thought to be essentially our brains' way of processing recent events and storing them away during REM sleep – so all people dream, regardless of whether they can see or not. However, the types of dreams we have do vary. Studies indicate that the dreams of people who have been blind since birth are governed by the other senses, such as sound, touch and scent. However, if a person becomes blind at around five to seven years old, they are likely to still experience some visual elements in their dreams, though only of the things they encountered *before* losing their sight. For example, the faces of new people they meet after going blind are likely to be estimations based on faces they have previously seen.**


Regardless of visual sight (or unusual sleeping arrangements), dreams are an important part of our brain function

© Corbis; Alamy; Thinkstock

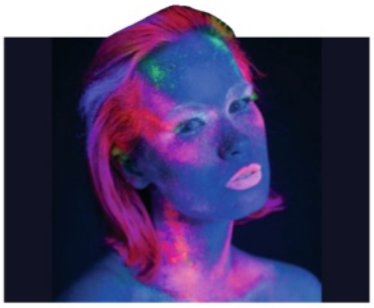
*“The innovations feature got me excited about what 2014 has in store in science and technology”*

## Beyond the snow…

Dear Editor,
I loved issue 55 of **How It Works**. The innovations feature has really got me excited about what 2014 has in store in the realms of science and technology – though if I’m honest there were one or two that I have my reservations will appear this year, but I’m more than happy to be proven wrong.

The thing I most took from the issue, however, was a whole new perception of Antarctica. I’ve always just thought of it as a barren expanse of snow and ice at the bottom of our world, but two of your features have shown me otherwise. I never thought such an inhospitable place could host so much wildlife (from whales to ancient bacteria) and also be such a big destination for research (eg IceCube). Despite outer appearances it truly is a hotbed for science.

Best,
**Audrey Stanton**



## Glowing enquiry

Hi **HIW**,
Have you ever done an article on glow-in-the-dark paint? That’s something I’d love to know – I’m currently wearing some on my shirt!
**Laura Malarkey**

**Good question, Laura – so good, in fact, that we’ll answer it in a future issue in the Brain Dump section! For now, let us tide you over with what makes fluorescent ink brighter than normal ink: bit.ly/1exuWB6.**


## What’s happening on… Twitter?

We love to hear from **How It Works**’ dedicated followers. Here we pick a few tweets that caught our eye this month…

Adam Wright @aw21097
**@HowItWorksmag** what an amazing prize #win #FreebieFriday :)

Antônio Cesar Moraes @antoniocesarm
Just bought the digital version of **@HowItWorksmag** for iOS. Amazing!

Liam Kelly @liamkellylk23
OMG!! I am going crazy at the sight of this in your magazine! **@HowItWorksmag** THANKS! Issue 55 is great :D

Burnham RNLI @BurnhamRNLI
**@ExmouthRNLI @HowItWorksmag @RNLI** superb, really enjoyed that (especially from the comfort of my sofa). Bet you guys cannot wait!

Miguel Davis @migs_1999
**@HowItWorksmag**
I would like to know how to shoot a crossbow. (How to skills). Miguel

krs @KRS_OVO
**@HowItWorksmag** is the most entertaining magazine ever to me. Ever.

## Big Bang theory

Hi **HIW**
Although not currently a subscriber to **How It Works**, my daughter subscribed to your magazine for her husband and sent me 12 back issues. I am much impressed and gave some to a very bright elementary school lunch buddy I mentored in science and chemistry, and two local schools. In issue 54’s ‘The nature of space-time’ box [page 62], I wondered if any theories exist on the distribution of elements in the universe excluding the obvious preponderant presence of hydrogen?
**Mike Gaston**



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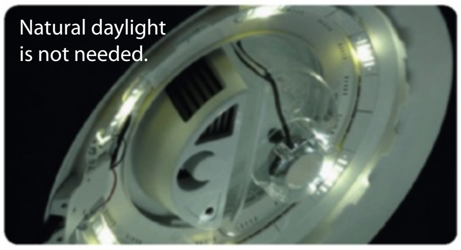


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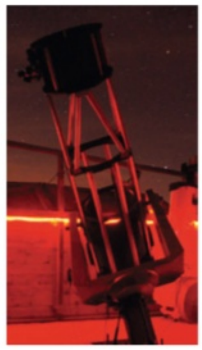

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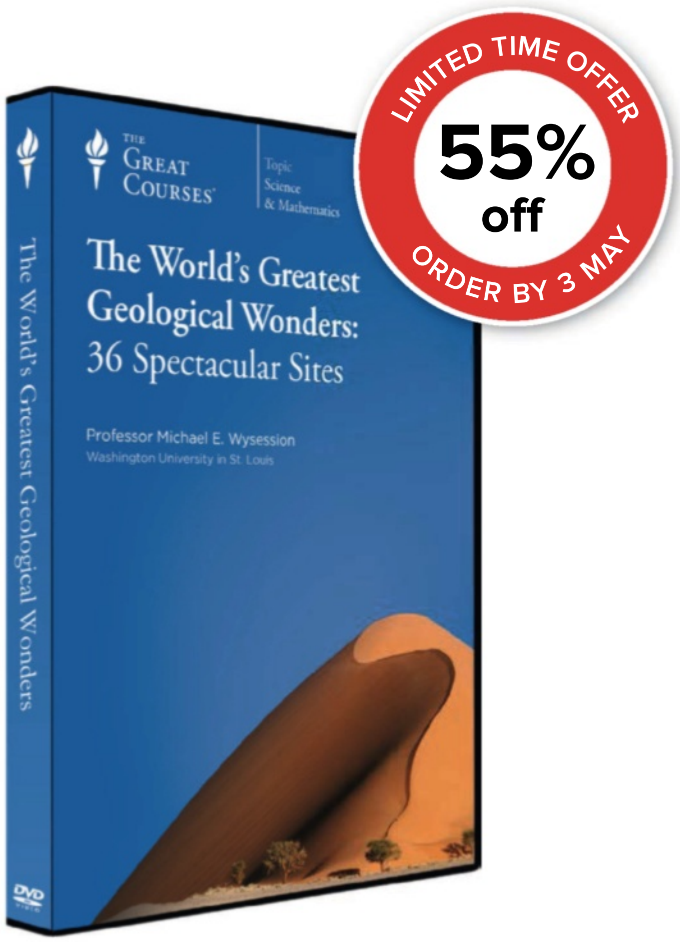


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